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REPORT ON THERMAL POLLUTION OF INTRA-
STATE WATERS, BISCAYNE BAY, FLORIDA

Federal Water Pollution Control Administration
Fort Lauderdale, Florida

February 1970

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REPORT ON
THERMAL POLLUTION OF INTRASTATE WATERS
OF
BISCAYNE BAY, FLORIDA

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U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST WATER LABORATORY
Technical Services Program
Lower Florida Estuary Study ✓
Ft. Lauderdale, Florida

February 1970

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I. INTRODUCTION

In December 1967, the Governor of Florida and the Florida State Board of Health requested assistance from the Federal Water Pollution Control Administration in making an environmental study of Biscayne Bay and a comprehensive study of Lake Worth. The Governor specifically requested an evaluation of the effects of heated water discharge from a planned nuclear power plant on the quality of Biscayne Bay.

In the summer of 1968, personnel from the Southeast Water Laboratory, Athens, Georgia, conducted an extensive temperature monitoring study of the lower bay. The results of this study are contained in a report "Temperature Studies, Lower Biscayne Bay," October 1968, and are included as Appendix A to this report.

In the spring of 1969, a permanent team of investigators was assigned to the area to conduct studies of the lower Florida estuary area, including Lower Biscayne Bay.

This report on the effects of heated effluent on Biscayne Bay near Turkey Point and on the present water quality and biological system of Biscayne Bay and Card Sound is based on: previous reports, investigations of the University of Miami Institute of Marine Sciences, information and data furnished by the Florida Power and Light Company, and field investigations by the Federal Water Pollution Control Administration.

The cooperation and assistance of the several agencies and individuals who have contributed to this effort is gratefully acknowledged.

II. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Severe damage has occurred to the aquatic plant and animal population of Lower Biscayne Bay due to the present heated effluent from the Turkey Point plant of the Florida Power and Light Company.

2. No man-made pollution or any physical condition other than elevated temperature is present which could account for the observed biological damage in Lower Biscayne Bay.

3. Under the most conservative present operating conditions, the temperature rise of the cooling water, across the condensers, will exceed 10°F at least 16% of the time.

4. The cooling water effluent discharged from Grand Canal moves in a northeasterly direction around Turkey Point. This path coincides with the zone of biological degradation.

5. The biological degradation zone covers about 670 acres of Lower Biscayne Bay as observed during the summer of 1969.

6. A wide variety of both aquatic plants and animals were killed in late June 1969. This damage to aquatic life and vegetation is directly attributable to the discharge of heated effluent from the Turkey Point facility of Florida Power and Light Company.

7. The monthly mean of the maximum daily temperatures in areas of Lower Biscayne Bay outside the influence of artificially elevated temperatures resulting from waste cooling water is 83°F in June, 35.6°F in July and 87.3°F in August. (1968)

8. The additional operation of two nuclear powered generating units at the Turkey Point plant will increase the waste heat load by four times over that presently discharged (without proper thermal control). This increased heat load will intensify the present damage in extent, severity and frequency.

9. If waste heat from the Turkey Point facility is discharged to Card Sound, as presently proposed by the Florida Power and Light Company, temperatures in excess of 95°F can be expected in at least 35% of Card Sound, five percent of the time.

B. Recommendations

1. The Florida Power and Light Company shall abate the excessive waste heat load being discharged from its Turkey Point power plant to the levels recommended by the National Technical Advisory Committee to the Secretary of the Interior for estuarine waters. The Committee has recommended that the monthly mean of the maximum daily temperatures should not be raised more than 4°F during the fall, winter and spring (September through May) or by more than 1.5°F during the summer (June through August).

2. The Federal Water Pollution Control Administration in cooperation with the State of Florida and the Florida Power and Light Company establish a temperature monitoring program to determine compliance with the recommended temperature requirements as above.

III. AREA

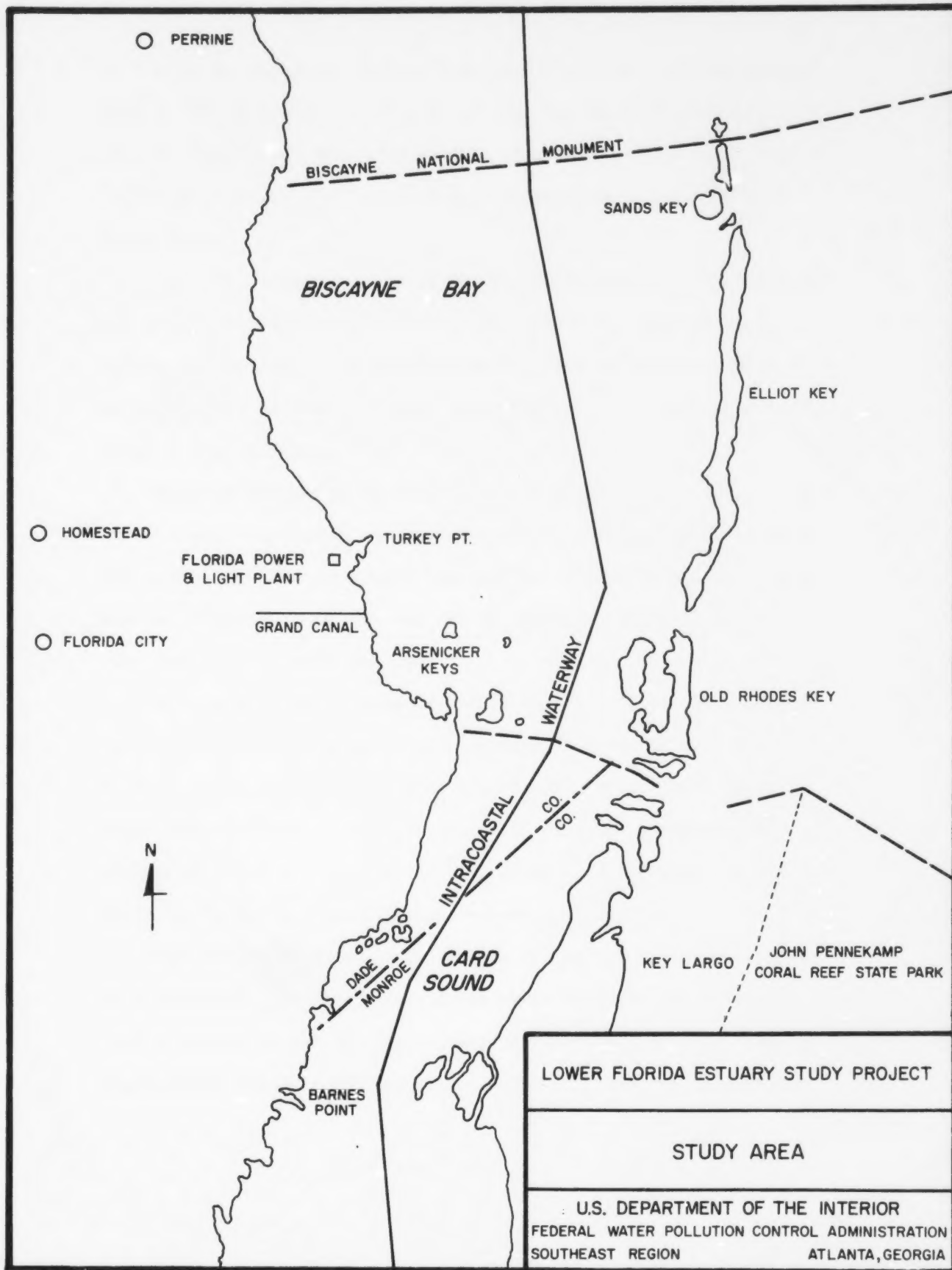
LOWER BISCAYNE BAY AND CARD SOUND

Biscayne Bay is a shallow subtropical estuarine lagoon lying on the extreme southeastern tip of the Florida peninsula south of Miami. The bay is semi-enclosed, being separated from the Atlantic Ocean by a narrow chain of barrier islands. Broad shoals and deep narrow tidal surge channels provide the connection to the ocean (Figure 1).

Lower (southern) Biscayne Bay is an area approximately 11 miles long by 9 miles wide and is bounded on the west by the Florida mainland, on the north by Featherbed Bank, on the east by the Florida Keys, and on the south by Cutter Bank. The bay is shallow, with a maximum depth of 13 feet and an average depth of between 5 and 6 feet at mean low water (MLW). The mean tidal range near Homestead on the western shore is 1.65 feet and at Elliott Key on the eastern shore is 1.54 feet.

Card Sound is a relatively small basin adjacent to Lower Biscayne Bay. Card Sound is separated from South Biscayne Bay by the Arsenicker Keys and by the shallows formed by Cutter Bank. It is bounded by north Key Largo on the east and separated from Little Card Sound on the south by Card Bank.

Card Sound is roughly three miles wide by five and one-half miles long. The average depth at mean low water is about nine feet; however, the major portions of Card Sound are uniformly about ten feet deep at mean low water.



With the exception of Card Bank at the southern end and Cutter Bank at the northern end, Card Sound does not have the extensive shallow "grass bed" shoreline typical of Lower Biscayne Bay. The bordering subtidal shallows drop precipitously into a deeper Card Sound Basin.

The tidal exchange of water between Card Sound and Lower Biscayne Bay is over the shallows of Cutter Bank, which at mean low water ranges from six inches to two feet deep. Flow to the south must pass over Card Bank and through the narrow passage from Little Card Sound to Barnes Sound.

Exchange of Card Sound water with the ocean is confined to the surge channels or creeks at north Key Largo; namely, Angelfish Creek and Broad Creek. Before these channels enter Card Sound, they form shallow dendrite paths over the top of shallow banks from one to four feet deep at mean low water.

The input of fresh water to Card Sound from land drainage is limited to runoff from Key Largo, the mainland east of salt water barrier levee, and from the Model Land Canal. Thus, fresh water input is most likely limited to the small drainage southeast of Florida City and is intermittent with slugs of fresh water to the Sound during and following periods of heavy rainfall.

The climate of Dade County is warm and mild and may be described as subtropical. Extreme temperatures range from the mid 90's in July or August to mid 30's in January or February. However, average temperatures for July and August are about 82⁰F and for January and

February are about 69°F. Annual rainfall is about 60 inches with 75-80 percent occurring June through October. During that same period, the relative humidity is quite high, ranging from 60 to 90 percent of saturation.

IV. WATER USE

At present, Biscayne Bay is used for commercial and sport fishing, shellfishing, commercial sponge harvesting, sailboating, motor boating, wading, skiing, swimming, snorkel and SCUBA diving and aesthetic enjoyment.

Few places in the world have more beautiful or spectacular birds than South Florida. Most important in Biscayne Bay are the wading and shore birds. These are found principally in the shallows, extensive mangrove shoreline and the small mangrove islands in the extreme south portion of the bay. Several species can usually be seen wading in the shallows, among them some of the rare and endangered species. Birds commonly observed include heron, pelican, cormorant, egret, white ibis, roseate spoonbill, frigate birds, waterfowl, gulls and terns.

Plants of Biscayne Bay serve a valuable ecological purpose, including the production of a rich substrate supporting and sheltering invertebrate population and stabilizing the bay bottom and the shoreline. The richly vegetated bay bottom serves as a nursery for the valuable sport and commercial fishery and has an important role in the productivity of all the marine resources in the area. These animals and plants are the nutrient base of all life in the bay.

There are in Biscayne Bay at least 27 species of fish which are of major importance for commercial, sport, or bait fishing, including mullet, barracuda, mackerel, jack, snapper, grouper, bonefish, snook

and pompano. There are at least nine invertebrates occurring in the bay which are of major importance. These include sponges, queen conch, blue crab, stone crab, shrimp, and spiny lobster. In addition, there are at least 18 species which are of minor commercial significance. (1)

In 1965, bait shrimp fishery alone had a value of \$393,600. Stone crabs were the second most valuable commercial fishery, netting a catch valued at \$145,828 in 1965. Spiny lobsters from Biscayne Bay brought \$81,000 to commercial lobstermen. In addition, a considerable but unrecorded sport fishery also exists. (1)

For residents of South Florida, Biscayne Bay offers the most convenient, attractive and diverse recreational opportunities. It is projected that 2.7 million people will reside in the four-county area (Dade, Broward, Palm Beach and Monroe) by 1980. Of that number, approximately one million will be in the 18-44 age group -- the active years for outdoor recreation. By that time, an estimated 1.36 million instances of participation in outdoor recreation will occur, of which water-oriented activities will account for about 78 percent. (2)

According to a 1967 tourist study conducted by the Florida Development Commission, 73 percent of the tourists entering Florida by all means of transportation looked forward to beaches and swimming. (2)

The Congress of the United States, on October 18, 1968, enacted PL 90-606 authorizing \$24,575,000 for the purchase of property for the Biscayne National Monument and \$2,900,000 for Monument development. In doing so, the Congress recognized the unique value of this

subtropical estuary lagoon area and set it aside as a preserve for the enjoyment of the public. The purpose of authorizing the Monument's establishment was to "...preserve and protect for the education, inspiration, recreation, and enjoyment of present and future generations a rare combination of terrestrial, marine, and amphibian life in a geographical setting of great natural beauty...." (3)

The Biscayne National Monument would be located in Lower Biscayne Bay, approximately 20 miles south of Miami. The entire area within the Monument would be about $11\frac{1}{2}$ miles from north to south and an average of 12 miles from east to west. It would consist of about 96,300 acres, 3,900 acres of which are land and mangrove swamps consisting of the Upper Florida Keys, a chain of narrow islands separating Biscayne Bay from the Atlantic Ocean. About 92,400 acres (approximately 96%) are submerged, consisting of the adjoining bay and ocean waters, and is accessible only by boat. (See Figure 1.)

The boundaries of the Monument would encompass some 33 islands and keys lying between but not including Key Biscayne and Key Largo. The keys included in the Monument are among the most northerly of the chain of islands stretching from Virginia Key, just south of Miami Beach, to Key West and beyond. Principal keys within the area are the 1,700-acre Elliott Key and Sands, Adams and Rhodes Keys; many other keys a fraction of an acre in size would also be included.

On the north, the boundary runs between Boca Chita and Sands Keys; on the east it follows the 60-foot depth line in the Atlantic Ocean; on the south it runs along the northern boundary of a possible

shipping channel entering into Broad Creek; on the west it generally follows the outer dredging limit line established by the Dade County Commissioners, generally parallel to and within 400 to 1,000 feet from the mainland. The extension of the west boundary of the Monument to near the mainland is intended to protect the submerged lands of Biscayne Bay from unwarranted channel development, commercial dredging and filling, pollution, and other activities which may alter or upset the marine ecology and underwater circulation patterns.

Title to all but about 400 acres of the submerged land in Biscayne Bay plus part of the submerged land on the ocean side of the keys is held by the State of Florida. The remainder is held by the United States. The State, by resolution dated July 9, 1968, acting through its Internal Improvement Fund (IIF), has agreed to turn over State-owned submerged land to the United States subject to (1) Congressional authorization and designation of the proposed Monument, and (2) Congressional authorization for appropriation of Federal funds for acquisition of all non-Federally owned lands within the Monument area, with such acquisition to provide just compensation to owners.

An area not to exceed 80 acres has been planned on the mainland as a headquarters site near Homestead Bayfront Park, and an area not to exceed 40 acres is also planned on Key Largo as a secondary visitor contact station along Card Sound in the northern part of Key Largo. This would provide access to the Monument from Card Sound.

A visitor contact point is projected at Elliott Key. Developments are planned for shelters, enlarged docking facilities and primitive campgrounds at this location. Fishing, diving, snorkeling, bicycling, picnicking and hiking may be enjoyed.

A secondary public-use facility to supplement the one on Elliott Key would be on Sands Key to the north. Visitor contact, picnicking, and boat docking will be available. A similar facility would be located on Adams Key to the south.

The results of an economic study of the Monument's feasibility include the projection that by 1975 approximately 750,000 persons will be visiting the Monument on an annual basis, and the related annual expenditure at or near the park has been estimated to be \$9,150,000. (2)

V. TURKEY POINT POWER PROJECT

A. Present Operation

The Dade Metro Commission granted the Florida Power and Light Company a permit in June 1964 and construction of the two oil-fired units (referred to as Units 1 and 2) began in September of that year. Unit 1 was placed on line April 22, 1967 and Unit 2 went into operation April 25, 1968. These two conventional (oil-fired) units represent the presently installed capacity of the Turkey Point Power Plant. The plant is located on 3500 acres at and adjacent to Turkey Point (Figure 2).

Units 1 and 2 each have 432,000 KW maximum capacity, with normal load capacity of 360,000 KW. Each unit requires 635 cubic feet per second (cfs) of condenser cooling water, or a total of 1270 cfs (820 million gallons a day) for both units. Water for cooling purposes is drawn from Biscayne Bay at an intake located just north of and immediately adjacent to Turkey Point. It is discharged back into the bay about two miles south of Turkey Point via a series of canals located on FP&L property.

The amount of water flowing through the condensers remains constant so that the rise in water temperature is a function of power generation load. Projected temperature rise across the condenser at various power loadings is shown in Figure 3. At the normal full load of 360,000 KW the temperature rise is approximately 12^o F and at maximum capacity of 432,000 KW the temperature rise is approximately 14^o F.

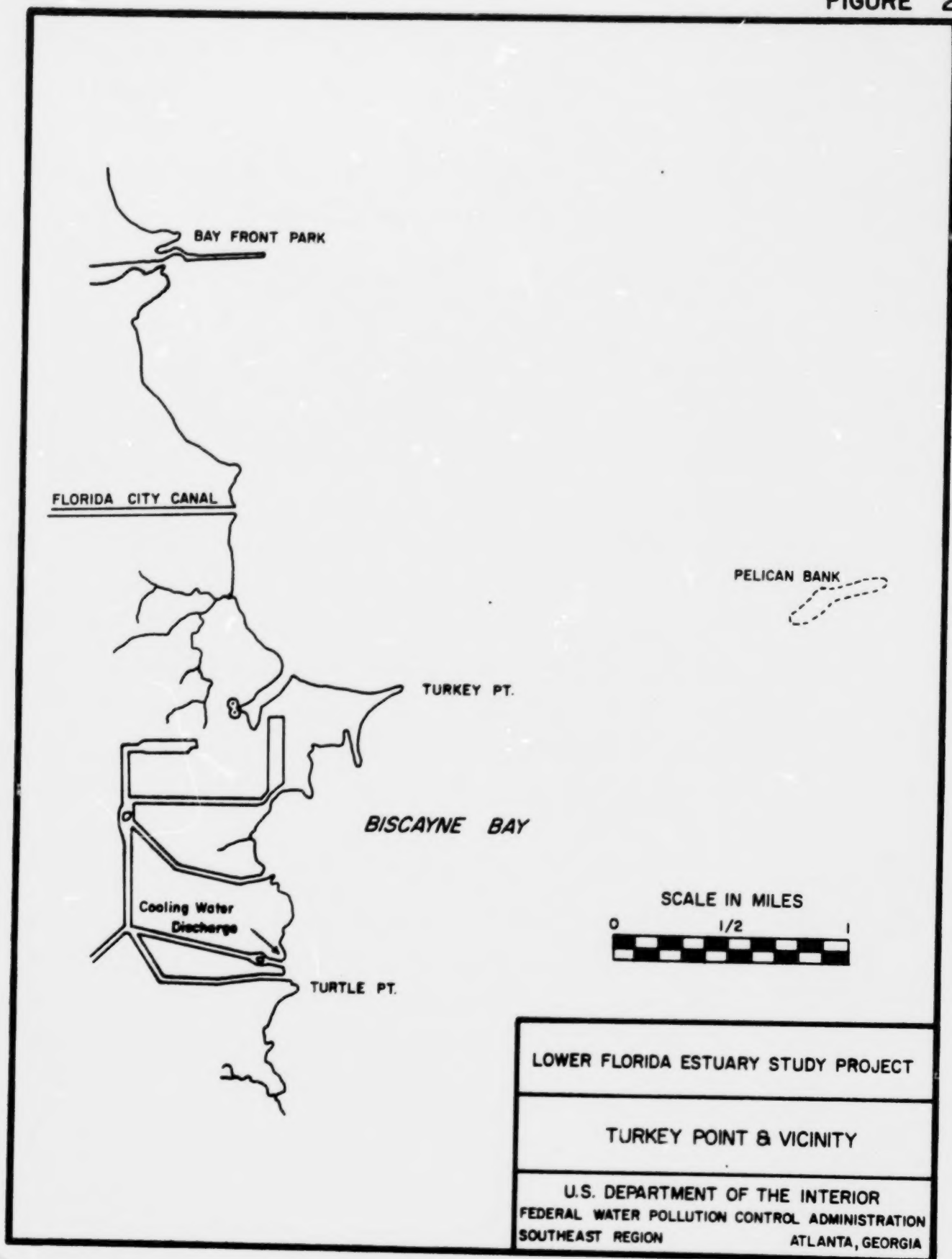
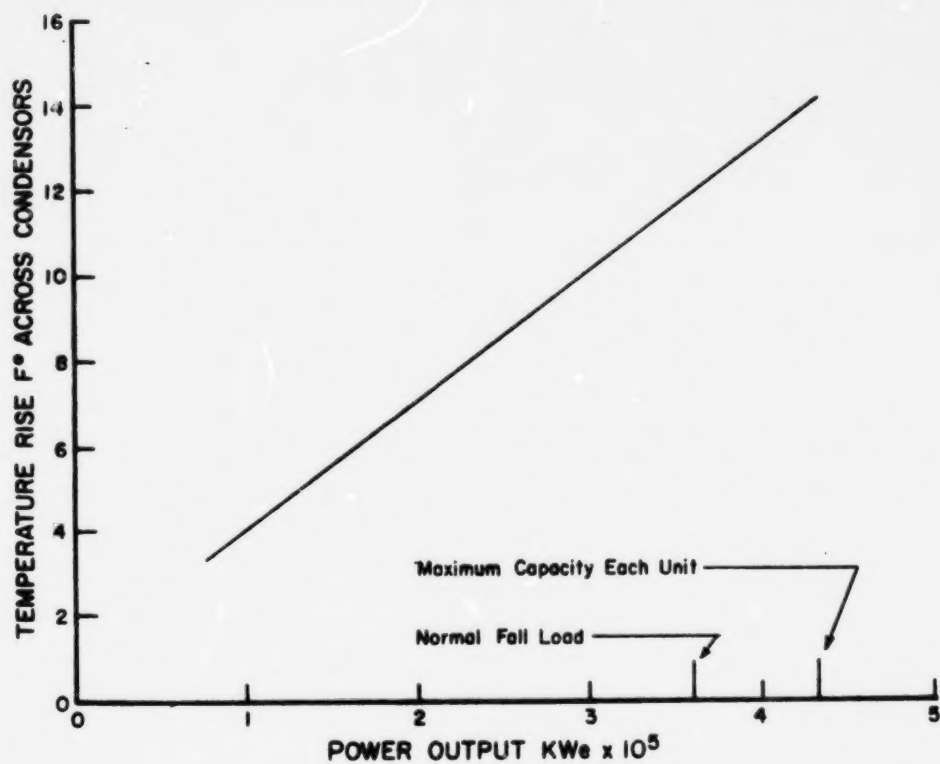


FIGURE 3

PREDICTED TEMPERATURE RISE FOSSIL UNITS 1 & 2

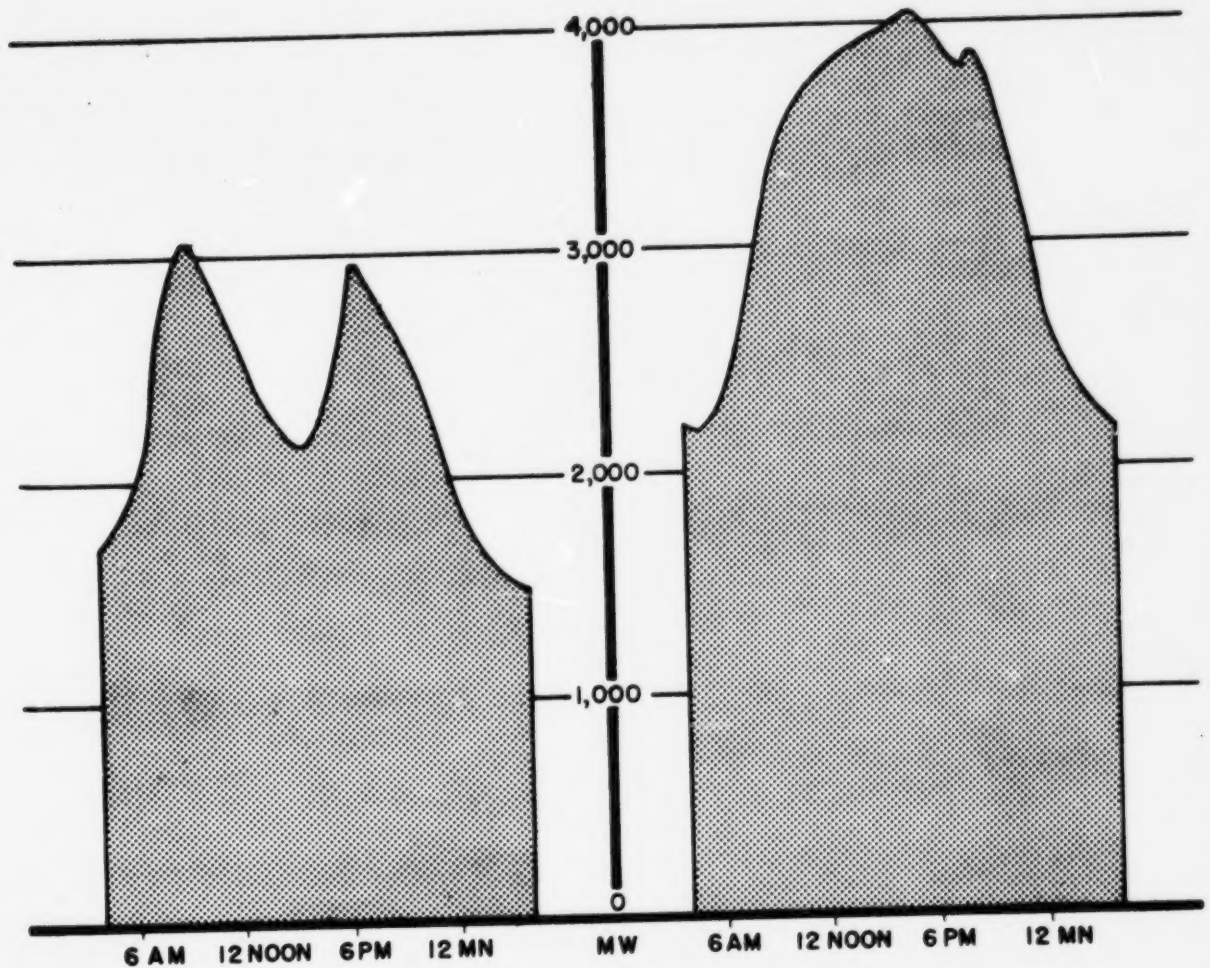


Hourly observations of power load at the Turkey Point plant and for the Florida Power and Light system as a whole for the months of June, July and August 1969 were supplied by the Company. These data indicate a wide daily fluctuation in power demand at Turkey Point ranging from 150,000 KW to over 780,000 KW. The highest peak occurs in the mid-to-late afternoon reflecting the summer air-conditioning demand. Typical winter and summer load curves prepared by Florida Power and Light are shown in Figure 4.

Figures 5, 6, and 7 show the frequency with which the expected temperature rise was equalled or exceeded during June, July and August 1969, respectively, at the Turkey Point installation. In June, the temperature rise across the condensers exceeded 3.3°F 100 percent of the time; it exceeded 9.9°F 50 percent of the time, and it exceeded 12.0°F 16 percent of the time. As a result of a fish kill which occurred on June 25, 1969 in Lower Biscayne Bay, operation of the Turkey Point plant and the South Florida power network was modified so that the Turkey Point plant would be the last plant to go to peak load and the first to come down from peak load.^{1/} As a result, the temperature rise frequency distribution for July 1969 shows a considerably different pattern from that in June. In July, the temperature rise exceeded 6.3°F 50 percent of the time, and exceeded 12°F 5.5 percent of the time. In August, the frequency of the 12°F temperature rise increased to 16.4 percent of the time. Fifty percent of the time the temperature rise equalled or exceeded 9.8°F , and a rise of 3.3°F was equalled or exceeded 100 percent of the time.

^{1/} Personal communication with Mr. C. M. Davis, Vice-President, FP&L Co.

SYSTEM DAILY LOAD CURVES

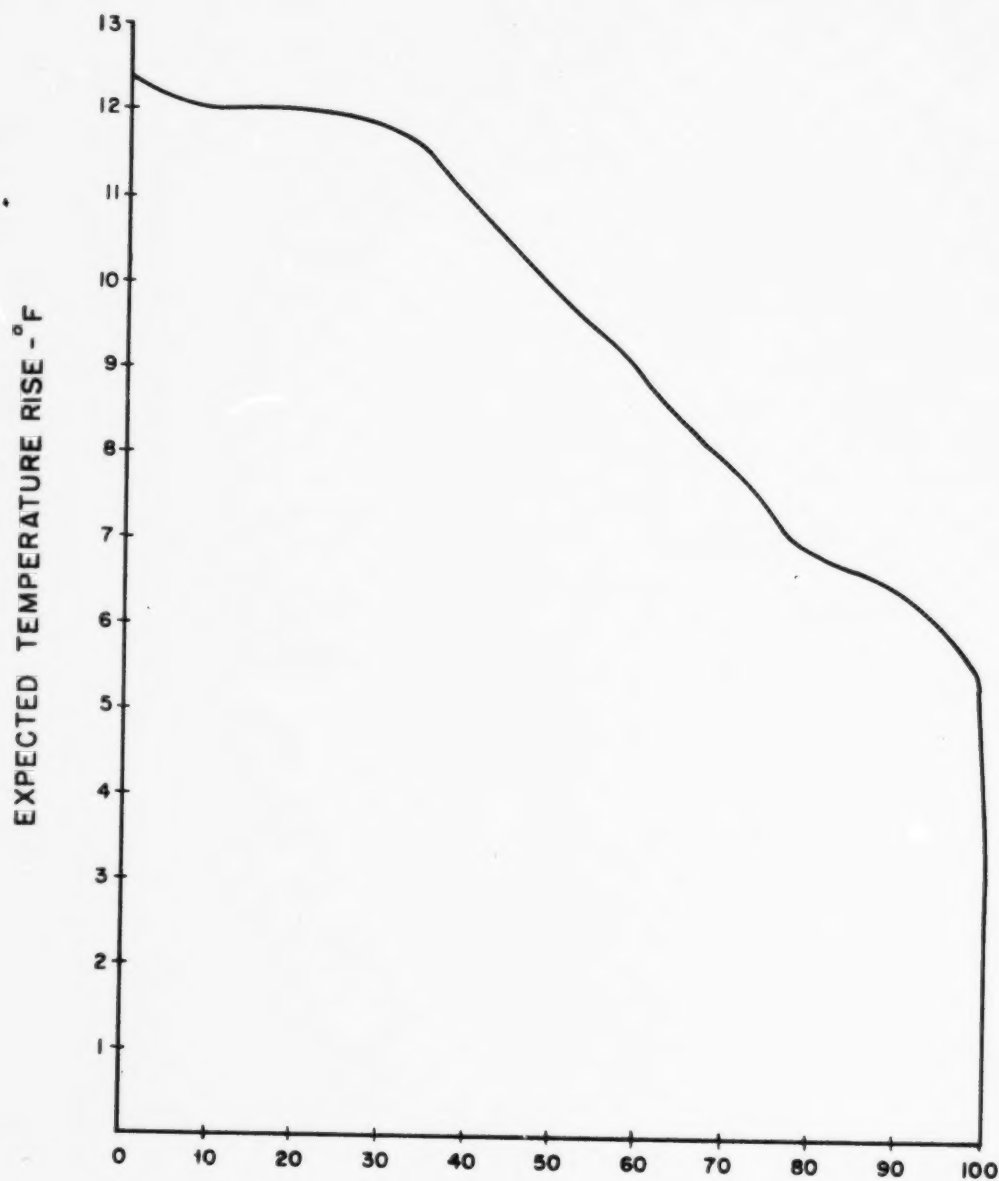


WINTER

SUMMER

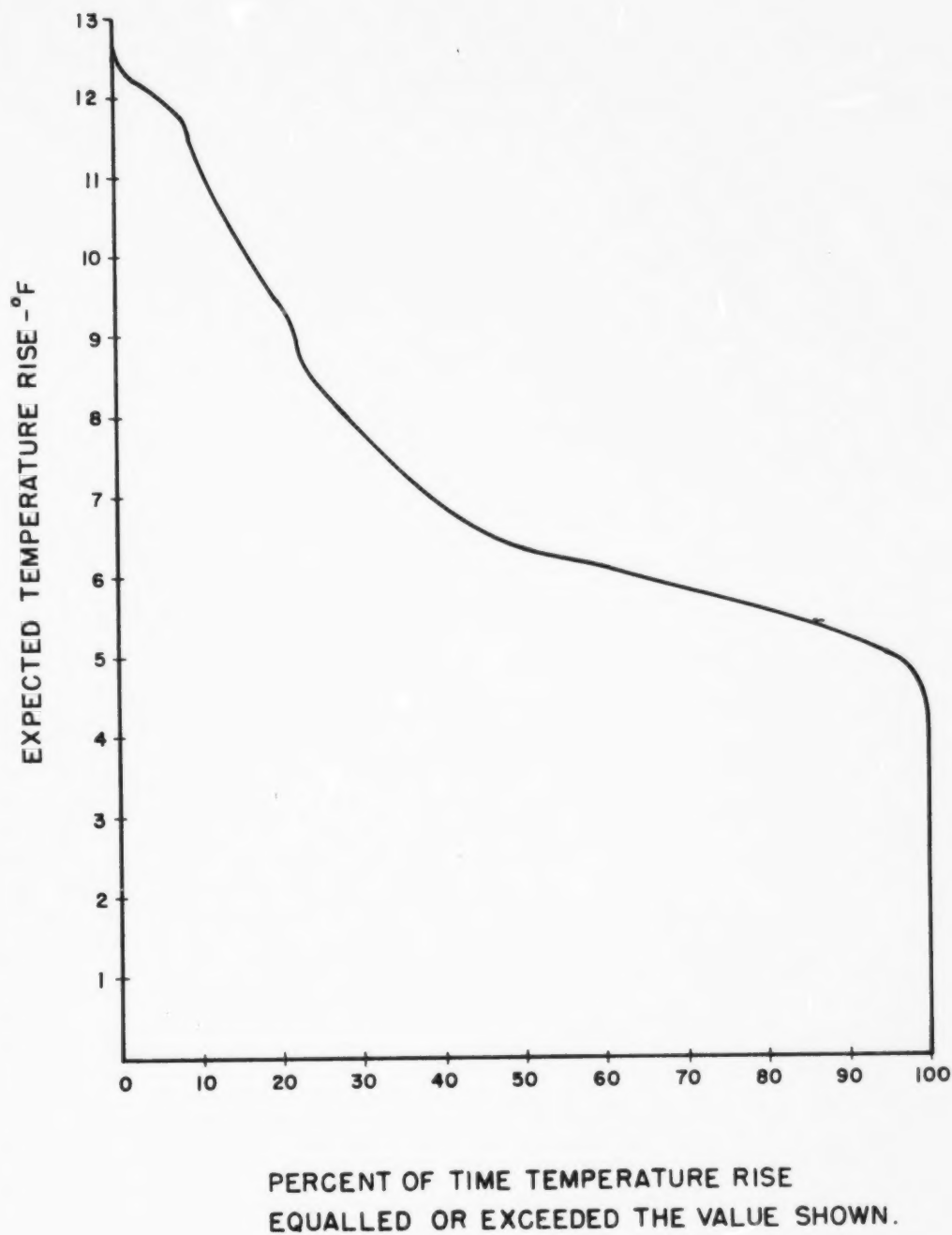
1968

FREQUENCY DISTRIBUTION OF TEMPERATURE RISE ACROSS
CONDENSERS AT TURKEY POINT UNITS 1 & 2 JUNE 1969



PERCENT OF TIME TEMPERATURE RISE
EQUALLED OR EXCEEDED THE VALUE SHOWN.

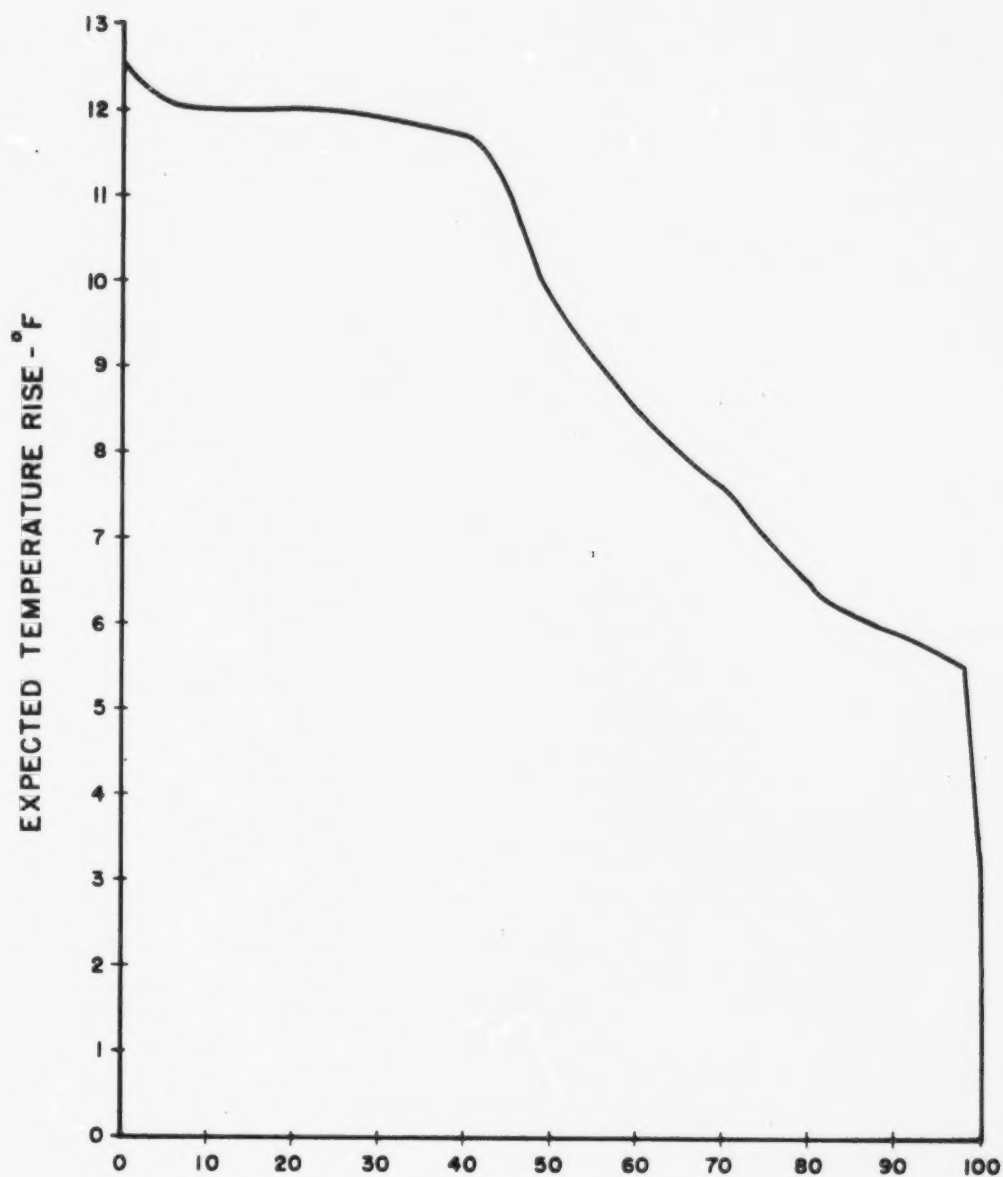
FREQUENCY DISTRIBUTION OF TEMPERATURE RISE ACROSS
CONDENSERS AT TURKEY POINT UNITS 1 & 2 JULY 1969



13-d

FIGURE 7

FREQUENCY DISTRIBUTION OF TEMPERATURE RISE ACROSS
CONDENSERS AT TURKEY POINT UNITS 1 & 2 AUG. 1969



PERCENT OF TIME TEMPERATURE RISE
EQUALS OR EXCEEDS VALUE SHOWN.

B. Planned Operation

On November 15, 1965, the Company announced plans to construct two 760,000 KW nuclear powered units at Turkey Point. Permits were acquired from the Atomic Energy Commission and the Dade Metro Commission. Construction was begun in early 1967 on Units 3 and 4. Construction is expected to be completed and the first nuclear unit on line in 1971. The second nuclear unit should go into service in 1972.

Each nuclear unit has a normal full load output of 680,000 KW and a maximum capacity of 760,000 KW. Condenser cooling water volume required is 1490 cfs per unit or a total of 2980 cfs. When combined with the fossil units, a total of 4250 cfs or 2.75 billion gallons a day of cooling water will be required at the Turkey Point generating facility.

Figure 8 shows the predicted temperature rise across the condensers of Units 3 and 4 under various power load demands. Under normal full load, the temperature rise would be 15.2°F and at maximum load it will be 16.8°F .

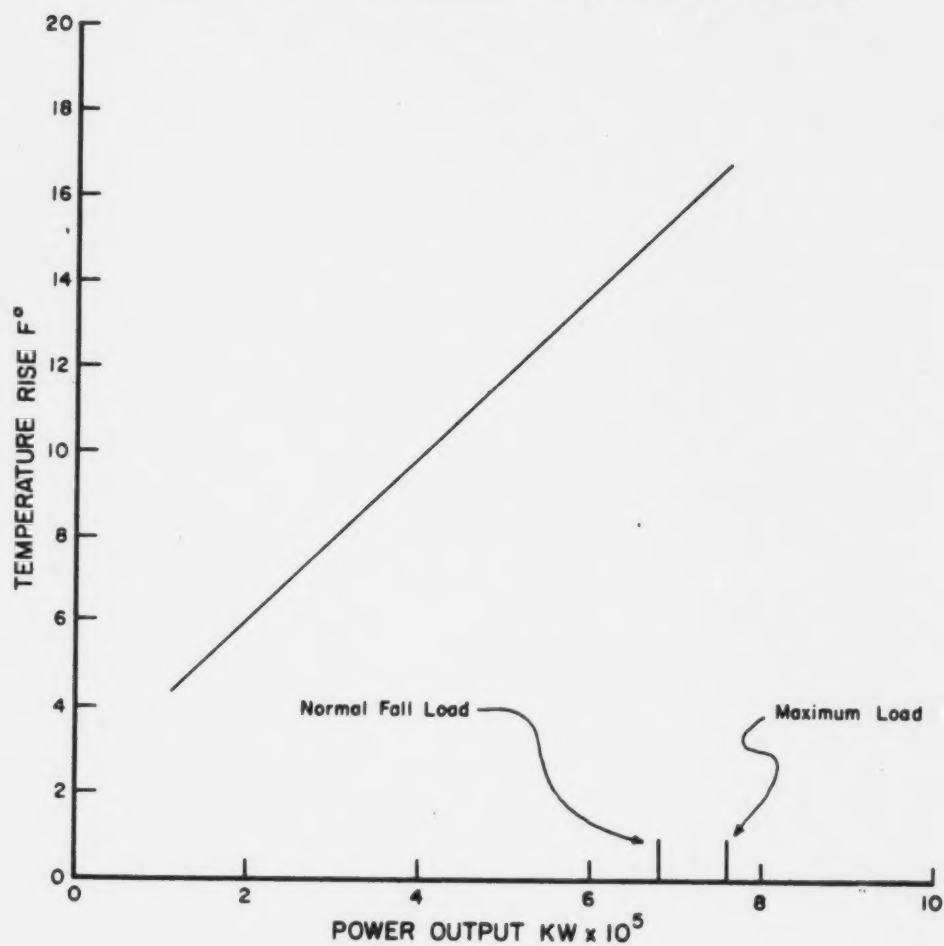
The combined temperature rise when all units at Turkey Point are operating under normal full load will be 14.2°F . Under maximum power demand the temperature rise will be 15.9°F .

The predicted waste heat load will be approximately four times as great with the nuclear units in operation as at present (0.98×10^6 BTU* per second at present; 3.9×10^6 BTU per second in the future at normal full load.)

* BTU = British Thermal Unit, a measure of heat content.

FIGURE 8

PREDICTED TEMPERATURE RISE NUCLEAR UNITS



VI. STATUS OF THERMAL CONTROL PROGRAM

Subsequent to the start of operation of Units 1 and 2, and after the issuance of the construction permit for Units 3 and 4, the Florida Power and Light Company, on October 16, 1968, applied to Dade County for a temperature variance. This variance was granted on February 20, 1969 and expired on July 31, 1969.

The Dade County temperature standard states that temperatures shall not be raised artificially to exceed 95°F. Water quality standards adopted by the State of Florida contain the following statement: "(The temperature) shall not be increased so as to cause any damage or harm to the aquatic life or vegetation of the receiving waters or interfere with any beneficial use assigned to such waters." All of Biscayne Bay is designated Class III: Recreation, Propagation and Management of Fish and Wildlife.

Beginning on June 23, 1969, a series of hearings was held by the Metropolitan Dade County Pollution Control Hearing Board. On November 18, 1969, the Board granted an extension of the temperature variance until July 1, 1971.

Florida Power and Light Company has presented a plan calling for: providing cooling and dilution water from Biscayne Bay, transporting the heated effluent to Card Sound via canal, and discharging 8500 cfs of cooling water at elevated temperature into Card Sound. At the present time, the Company discharges heated effluent through a system of canals directly to Biscayne Bay approximately two miles south of the plant.

VII. WATER QUALITY

A. Review of Previous Data

Water quality studies have been conducted in Lower Biscayne Bay and Card Sound by several organizations including the Department of the Interior, the University of Miami Institute of Marine Sciences, and Florida State Board of Health.

Conclusions of a State Board of Health report in 1962 were:

- 1) "The area of Biscayne Bay covered in this survey (between Featherbed Bank and Turkey Point) is chemically the equivalent of good, clean ocean water. Some fresh water influence is apparent at the sampling points in the general vicinity of the canal outfalls.
- 2) (Biologically) The lower part of the bay near Homestead is in a completely healthy condition.
- 3) The effluent from the Homestead sewage treatment plant...has caused a noticeably heavier growth of bottom vegetation near the mouth of the canal."
- (4) Actual data are not available to describe the load entering the bay from the Homestead sewage treatment plant; however, the 1962 Inventory of Municipal Waste Facilities shows a population of 8050, served by a biological secondary treatment plant which discharged an estimated population equivalent of 800.
- (5)

Unpublished data collected by the Institute of Marine Sciences, University of Miami, are primarily hydrographic, consisting almost entirely of temperature, salinity, and dissolved oxygen measurements. Examination indicates that during the summer months there are instances of dissolved oxygen concentrations reaching 3.0 mg/l or lower for

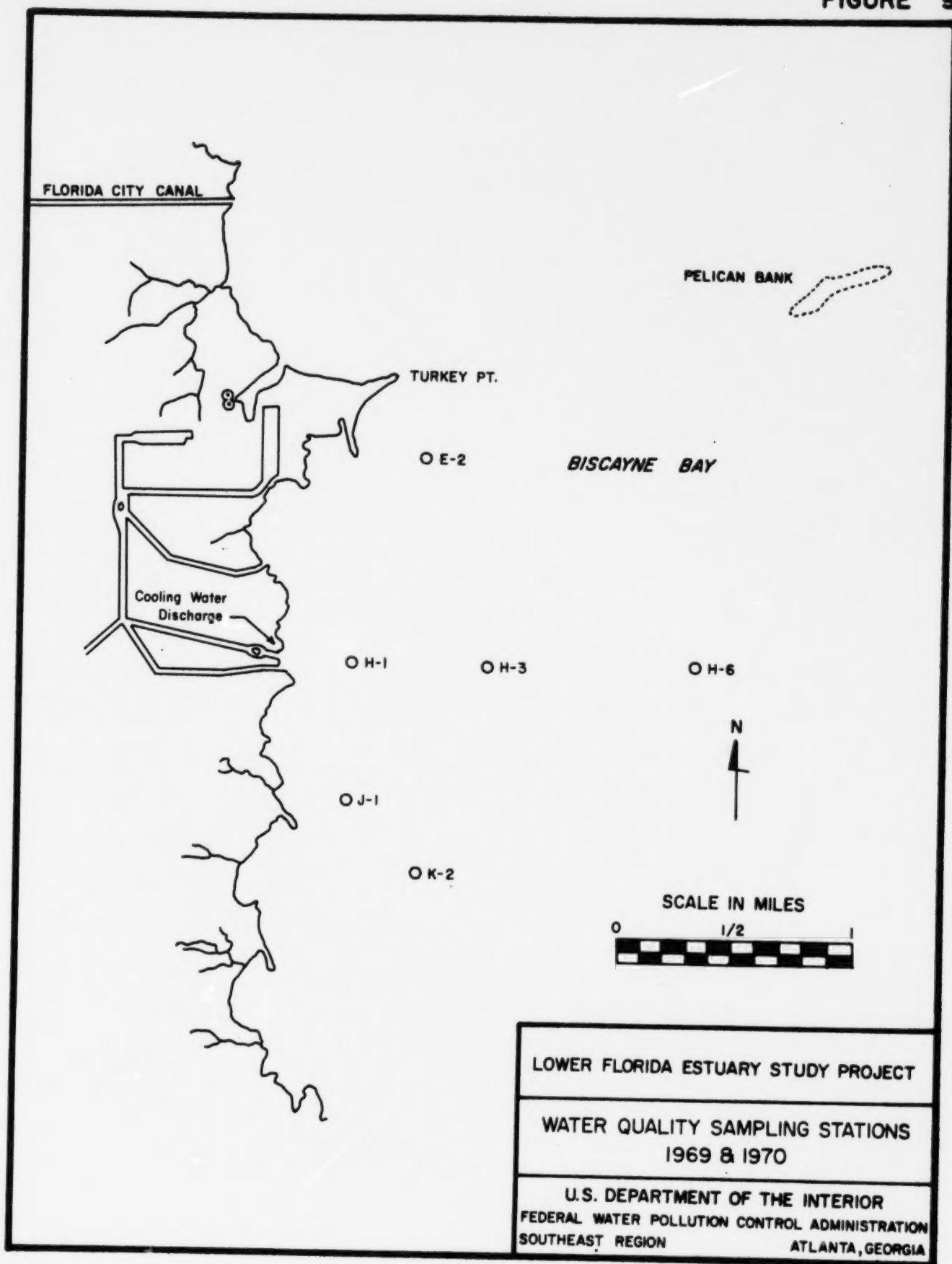
short periods of time. Data collected early in the morning have generally lower DO values than samples collected during midday or afternoon. This pattern is indicative of normal diurnal variations resulting from biotic respiration and has been observed during FWPCA round-the-clock surveys. Other than the instance above, all other data indicate that dissolved oxygen levels are well above 4.0 mg/l, the official Florida criterion.

Researchers at the University of Miami, School for Marine and Atmospheric Sciences, studying the effects of thermal pollution from Florida Power and Light's Turkey Point power plant have identified 58 species of fish, 87 molluscs, 46 crustaceans, 15 sponges, 16 echinoderms, 25 polychaetes and 5 miscellaneous animals collected in the vicinity of Turkey Point. In addition, 25 species of algae and marine "grasses" have been identified (Anon, 1969).

B. FWPCA Field Activities

Water quality studies were conducted in Lower Biscayne Bay between September 30 and October 2, 1969, and on January 17, 18 and 19, 1970. Samples were collected from the surface and bottom at two-hour intervals for a period of 48 hours at five locations adjacent to Turkey Point and east of Grand Canal, the major discharge point for the cooling water (Figure 9).

Air temperatures during the survey ranged from 74 to 91^o F and averaged 83.2^o F. Winds were generally from the south and varied from calm to 15 knots. Strongest winds were accompanied by a severe rain squall on the morning of October 2nd. Rain occurred



intermittently throughout the survey, with showers during the early morning and early afternoon. Associated cloud cover was quite heavy, generally above 50 percent. Seas were generally choppy but became calm around sunrise and sunset, and rough during squalls.

Highest water temperature occurred at Station H-1-T (500 yards east of Grand Canal). Temperature ranged from 84.0 to 93.5°F and averaged 89.2°F. Near the bottom at this Station (H-1-B), temperature ranged from 84.0 to 89.0°F and averaged 86.2°F. Analysis of the variance about the mean of these two data sets shows that the 3 degree difference is significant and indicates that the bay is thermally stratified at that point. No other station exhibited this degree of stratification (Table 1).

Temperatures at Station H-3 averaged 84.5 and 84.7°F at top and bottom, respectively. At Station H-6, 3000 yards east of Grand Canal, both top and bottom temperatures averaged 84.3°F.

Station E-2 is within the northward path of the heated water plume. Temperatures there were elevated to 88°F with no significant thermal stratification. Analysis of variance of the mean temperature at Stations H-1-S and E-2-S shows that the difference (1°F) is statistically significant. Similarly, the difference between E-2-T and H-6-T (3.9°F) is also significant.

Station J-1 is occasionally within the southern influence of the heated water plume. The temperature curve follows very closely the chloride curve, indicating that on flood tide the heated water is against the shore and expands to the south against its normal north-

18-a

TABLE 1

TEMPERATURE, DISSOLVED OXYGEN AND CHLORIDE CONCENTRATION

BISCAYNE BAY AT TURKEY POINT

9/30/69 thru 10/2/69

STATION		TEMPERATURE °F	DISSOLVED OXYGEN mg/l	CHLORIDE mg/l
E-2-T	Max	92.5	8.93	14600
	Min	84.0	5.02	11600
	Avg	88.2	6.45	13000
E-2-B	Max	92.5	9.65	15400
	Min	84.0	3.69	12300
	Avg	88.0	6.42	13400
H-1-T	Max	93.5	7.55	14200
	Min	84.0	4.98	9900
	Avg	89.2	6.05	11900
H-1-B	Max	89.0	7.73	15500
	Min	84.0	4.40	11300
	Avg	86.2	6.26	13200
H-3-T	Max	88.0	8.09	16300
	Min	80.0	5.39	13900
	Avg	84.5	6.55	14800
H-3-B	Max	88.0	8.11	16500
	Min	80.0	5.55	13900
	Avg	84.7	6.63	15300
H-6-T	Max	86.0	7.56	18500
	Min	83.0	5.46	15600
	Avg	84.3	6.25	16700
H-6-B	Max	86.0	6.94	19200
	Min	83.0	5.45	15700
	Avg	84.3	6.19	16700
J-1-T	Max	89.5	8.43	14400
	Min	81.5	5.08	10400
	Avg	85.2	6.51	12400
J-1-B	Max	89.5	8.70	15100
	Min	83.5	4.89	11100
	Avg	85.4	6.64	13900

ward flow pattern. Temperatures at J-1-T and J-1-B averaged 85.2 and 85.4[°]F, respectively, and were significantly different from those at Station H-1 but exhibited no statistically significant vertical thermal stratification.

At a recording monitor control station away from the influence of elevated temperature, on the southeast side of Arsenicker Key, the maximum temperature was 85[°]F and the minimum 84[°]F. The increase in temperature due to the cooling water discharge averaged 4.7[°]F and the maximum increase was 9[°]F. Temperature variation 500 yards east of Grand Canal was 9.5[°]F. Temperature variation at the control location was 1[°]F.

Concentration of chloride at Station H-1-T was the lowest of any station tested and averaged 11.9 gm/l. Concentration varied widely (9.9 to 14.2 gm/l), probably due to the frequent and locally heavy thunder storms and resultant runoff.

Station E-2-S, located some 1500 yards north and 500 yards east of Grand Canal, had an average chloride level of 13.0 gm/l. Station H-3, 1000 yards east of H-1, had an average of 14.8 gm/l. This reaffirms that water discharged from the canal moves northward along the shore. It also indicates that the less dense heated water, when combined with less dense surface drainage, produces an effluent which does not readily mix with the cooler and more saline waters of Biscayne Bay. This suggests a moderate to low coefficient of turbulent diffusion. Station J-1 also had slightly reduced chloride levels, further supporting this hypothesis.

Station H-3 shows very weak salinity stratification (500 mg/l in 5-foot depth) and Station H-6 had no vertical salinity stratification. There was less than 2.0 gm/l difference between the means of Station H-3 and H-6, indicating a narrower zone of fresh water influence in the easterly direction than in the northerly direction.

The lowest DO reading was 3.69 mg/l at Station E-2-B. The highest value of 9.65 mg/l was also observed at E-2-B. Diurnal variations were observed at all stations. These variations were generally the same magnitude at surface and bottom stations. The diurnal cycle of the DO curve in contrast to the 12.4 hour tidal cycle shows that the DO variations are not strongly related to the tide stage.

Alkalinity remained relatively constant throughout the sampling program. The greatest variation was from Station H-1 to H-3 to H-6. From a mean of 136 mg/l at H-1-T, the alkalinity dropped to 127 mg/l at H-3-T and 118 mg/l at H-6-T. It is interesting to note that alkalinity at H-3-B (118 mg/l) is the same as at H-6-T. This, along with the chloride concentrations, is evidence of some stratification at H-3, probably in the nature of a salt wedge. (Table 2)

The immense buffer capacity of sea water is reflected in the constant pH. Station H-1-T, which has already been shown to be different water from that at other stations, shows a pH of 7.8. This is 0.1 pH unit below the general level of the bay and is not considered a significant factor, especially in the light of the slightly higher alkalinity discussed above.

TABLE 2

SUMMARY OF CHEMICAL DATA

BISCAYNE BAY AT TURKEY POINT

9/30/69 thru 10/2/69

STATION	pH Units	ALKALINITY mg/l	TURBIDITY JCU	AMMONIA mg/l as N	NITRITE NITRATE mg/l as N	TOTAL KJELDAHL NITROGEN mg/l as N	BIOCHEMICAL OXYGEN DEMAND * mg/l
E-2-T	8.0	136	2.2	0.07	0.030	0.27	0.4
E-2-B	8.0	133	2.7	0.07	0.032	0.31	0.6
H-1-T	7.8	136	3.1	0.08	0.023	0.36	0.6
H-1-B	7.9	131	4.8	0.06	0.018	0.36	0.6
H-3-T	7.9	127	2.3	0.06	0.018	0.29	0.6
H-3-B	8.0	118	2.5	0.08	0.019	0.33	0.6
H-6-T	7.9	118	2.4	0.06	0.034	0.23	0.2
H-6-B	7.9	120	2.8	0.06	0.036	0.28	0.6
J-1-T	8.0	136	1.8	0.06	0.010	0.33	0.6
J-1-B	8.0	129	2.6	0.05	0.013	0.33	0.5

* 5 day 20°C

20-a

Turbidity was consistently low, having a maximum of 15.0 Jackson Candle Units (JCU) in one sample from Station H-1-B. The highest average value was also at H-1-B (4.8 JCU). The average at that station, disregarding the single high value, was 3.3 JCU.

Combined nitrite and nitrate nitrogen exhibited the highest average concentration at Station H-6-B, with 0.036 mg/l as N. The highest individual concentration was 0.060 mg/l at Station E-2-B at a high tide condition.

Highest values of total Kjeldahl nitrogen occurred at Station H-1. At that station, average concentration--both top and bottom--was 0.36 mg/l as N. At every station, Kjeldahl nitrogen was either the same top-to-bottom or the bottom sample was slightly higher.

Biochemical oxygen demand (5-day, 20°C) was, without exception, extremely low. Maximum observed BOD on an individual sample was 0.7 mg/l.

These data confirm that Lower Biscayne Bay is almost totally free of man-made organic pollution.

A second water quality survey was conducted on January 17, 18 and 19, 1970. Highest temperatures occurred at Station H-1 (Figure 9), ranging from 66.0°F to 79.0°F and averaging 75.5°F for the 48-hour period. Temperatures at Station H-3 averaged 69.0°F, while at Station E-2 they were 71.5, reflecting the northward movement of the heated water plume. Station K-2, south of the mouth of Grand Canal, also shows the influence of heated effluent with a temperature of 70.0°F, both top and bottom. Temperatures at Station H-6, 3000

yards east of Grand Canal, ranged from 66.0°F to 70°F, and averaged 68.0°F (Table 3). Temperature at the monitor control station averaged 70°F. This was 5.5°F less than that observed 500 yards east of the Grand Canal.

Chloride concentrations were generally higher than in the September survey, reflecting the seasonally reduced rainfall and fresh water inflow. Most stations showed 0.2 gm/l or less difference from top to bottom.

Dissolved oxygen was consistently high throughout the sampling period with a minimum value of 4.0 mg/l occurring at Station K-2-B. Maximum values were as high as 9.5 mg/l. There was no significant difference between dissolved oxygen concentrations in the mouth of Grand Canal and in the open bay.

Biochemical oxygen demand was higher during this survey than in the September study. A maximum value of 4.9 mg/l was observed at Station H-6-B. There is no readily apparent explanation for this phenomenon. The distribution does not show any relation to sources of waste. (Table 4)

As in the previous study, all other chemical parameters measured were found in extremely low concentrations. Turbidity had a maximum value of 2 JCU.

It is concluded from these investigations that the water quality of Biscayne Bay as measured by the standard chemical indicators is of extremely high purity and that no pollution is present which might cause damage to the aquatic environment.

TABLE 3
TEMPERATURE, DISSOLVED OXYGEN, AND CHLORIDE CONCENTRATION
BISCAYNE BAY AT TURKEY POINT
1/17/70 thru 1/19/70

STATION		TEMPERATURE OF	DISSOLVED OXYGEN mg/l	CHLORIDE mg/l
E-2-T	Max	74.5	9.5	15800
	Min	68.5	6.1	14300
	Avg	71.5	7.5	14800
E-2-B	Max	74.5	9.5	16300
	Min	68.5	4.8	14200
	Avg	71.0	7.4	14700
H-1-T	Max	79.0	8.4	15900
	Min	66.0	6.0	14100
	Avg	75.5	7.1	14900
H-1-B	Max	79.0	9.4	15700
	Min	66.0	6.1	14100
	Avg	75.5	7.3	14900
H-3-T	Max	71.0	8.4	15700
	Min	66.5	7.1	13800
	Avg	69.0	7.7	14600
H-3-B	Max	71.0	8.6	15800
	Min	66.5	6.8	13800
	Avg	69.0	7.6	14800
H-6-T	Max	70.0	8.5	16300
	Min	66.0	6.0	14900
	Avg	68.0	7.6	15500
H-6-B	Max	70.0	8.6	16700
	Min	66.0	6.8	14700
	Avg	68.0	7.6	15700
K-2-T	Max	73.0	8.8	15100
	Min	68.0	4.6	12300
	Avg	70.0	7.6	13900
K-2-B	Max	72.5	8.6	14800
	Min	68.0	4.0	12600
	Avg	70.0	7.5	13900

TABLE 4

SUMMARY OF CHEMICAL DATA

BISCAYNE BAY AT TURKEY POINT

1/17/70 thru 1/19/70

STATION	ALKALINITY mg/l	TURBIDITY JCU	AMMONIA mg/l as N	TOTAL		TOTAL PHOSPHATE mg/l as P	BIOCHEMICAL OXYGEN DEMAND *
				NITRITE NITRATE mg/l as N	KJELDAHL NITROGEN mg/l as N		
E-2-T	150	1	0.02	0.010	0.53	<0.05	1.1
E-2-B	149	1	0.02	0.009	0.34	<0.05	1.7
H-1-T	154	2	0.04	0.016	0.50	<0.05	3.2
H-1-B	153	1	0.02	0.015	0.46	<0.05	1.2
H-3-T	148	1	0.02	0.013	0.44	<0.05	3.4
H-3-B	149	1	0.02	0.011	0.43	<0.05	0.9
H-6-T	141	1	0.05	0.018	0.35	<0.05	3.5
H-6-B	142	1	0.03	0.017	0.36	<0.05	4.9
K-2-T	152	1	0.03	0.009	0.44	<0.05	0.9
K-2-B	154	1	0.02	0.008	0.52	<0.05	0.9

* 5 day 20°C

A water quality survey was conducted in Card Sound on January 15, 1970. Five locations were sampled, top and bottom, at two-hour intervals for a period of fourteen hours (Figure 10).

Temperatures in Card Sound ranged from 71.5°F at Station CS-1 to a low of 60.0°F at four stations. Highest average temperature was 66.5°F; also, at Station CS-1. Temperature stratification was apparent at the two stations in and near the mouth of Model Land Canal, with the warmer water lying on top. (Table 5)

Chloride data confirm a two-layered system near the mouth of Model Land Canal. Average chloride concentrations are 13.9 and 14.3 gm/l at Stations CS-5 and CS-1, respectively, while the bottom samples have chloride concentrations of 16.2 and 16.5 gm/l. All other stations show 0.2 gm/l or less difference between top and bottom, and these concentrations are all above 16.0 gm/l. These data indicate that Card Sound is more saline than Biscayne Bay--and this factor, together with the deeper water, provides a more oceanic habitat than that of Lower Biscayne Bay.

Dissolved oxygen levels were consistently high, with a minimum value of 5.0 mg/l and a maximum of 11.5 mg/l. Throughout Card Sound, the dissolved oxygen averaged about 8 mg/l. Weak but distinguishable oxygen stratification was noted at the two stations near Model Land Canal, with the lower values associated with the warmer and fresher water.

The highest ammonia and nitrate concentrations were at the mouth of Model Land Canal and were 0.10 and 0.035 mg/l, respectively.

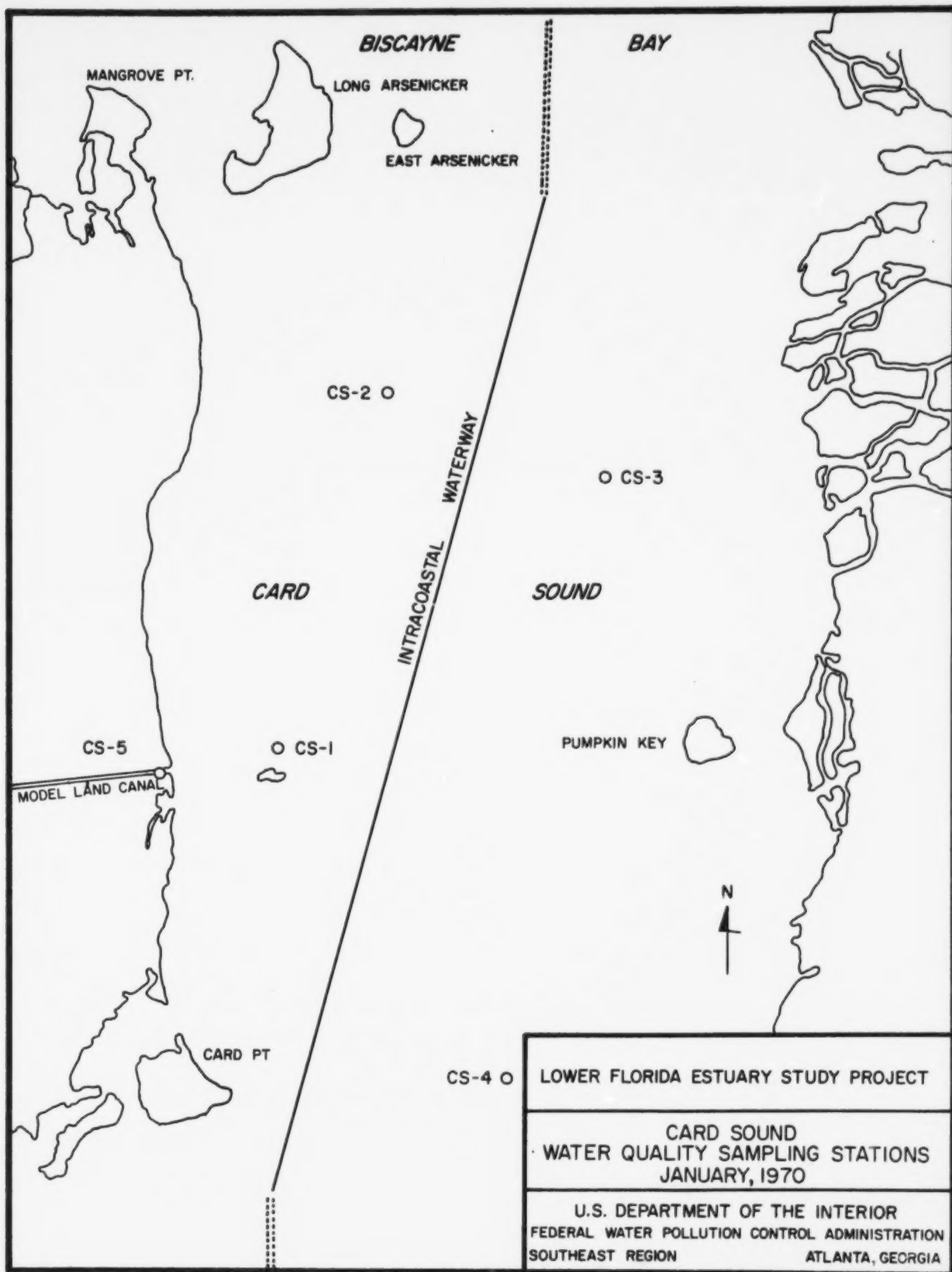


TABLE 5
TEMPERATURE, DISSOLVED OXYGEN, AND CHLORIDE CONCENTRATION
CARD SOUND
1-15-70

STATION	TEMPERATURE °F	DISSOLVED OXYGEN mg/l	CHLORIDE mg/l
CS-1-T	Max 71.5	8.5	16600
	Min 61.0	6.4	10400
	Avg 66.5	7.7	14300
CS-1-B	Max 63.5	9.4	16900
	Min 60.5	5.0	16000
	Avg 62.0	8.0	16500
CS-2-T	Max 63.0	11.5	16700
	Min 60.5	7.5	16000
	Avg 62.0	8.9	16500
CS-2-B	Max 62.0	11.2	17000
	Min 60.0	7.5	16200
	Avg 61.5	8.9	16700
CS-3-T	Max 63.0	8.7	17500
	Min 60.0	8.3	16700
	Avg 61.0	8.5	17000
CS-3-B	Max 62.5	8.5	17300
	Min 60.0	8.1	16000
	Avg 61.5	8.3	16800
CS-4-T	Max 62.0	8.7	17500
	Min 61.0	8.2	16200
	Avg 61.5	8.4	16600
CS-4-B	Max 62.0	8.9	17200
	Min 60.0	8.3	16100
	Avg 61.0	8.5	16600
CS-5-T	Max 68.0	8.9	17200
	Min 61.5	6.6	5800
	Avg 64.0	7.8	13900
CS-5-B	Max 63.5	8.6	16600
	Min 61.5	8.0	14800
	Avg 62.0	8.2	16200

Maximum total Kjeldahl nitrogen of 0.88 mg/l occurred at Station CS-1.

All total phosphate concentrations were below 0.05 mg/l. (Table 6)

Turbidity concentrations were 4 JCU maximum at Station CS-5 and generally 1 JCU through the Sound. Alkalinity ranged from 152 to 169 mg/l. Five day BOD in Card Sound showed a maximum concentration of 3.2 mg/l.

From these data, it is concluded that the water quality of Card Sound is excellent and that no pollution is present which might cause damage to the ecosystem of Card Sound.

C. Circulation (Lower Biscayne Bay)

A tracer study was conducted in Biscayne Bay in the vicinity of Turkey Point January 12-13, 1970. The specific purpose of this dye study was to determine the distribution of the FP&L power plant condenser cooling water discharge in Biscayne Bay.

Two hundred fifty pounds of 20 percent Rhodamine WT dye (50# of dye) was instantaneously discharged into Grand Canal at high-water slack (HWS) on January 12. Samples were collected on an hourly schedule at the water surface and bottom at each of 16 stations for the next 24-hour period.

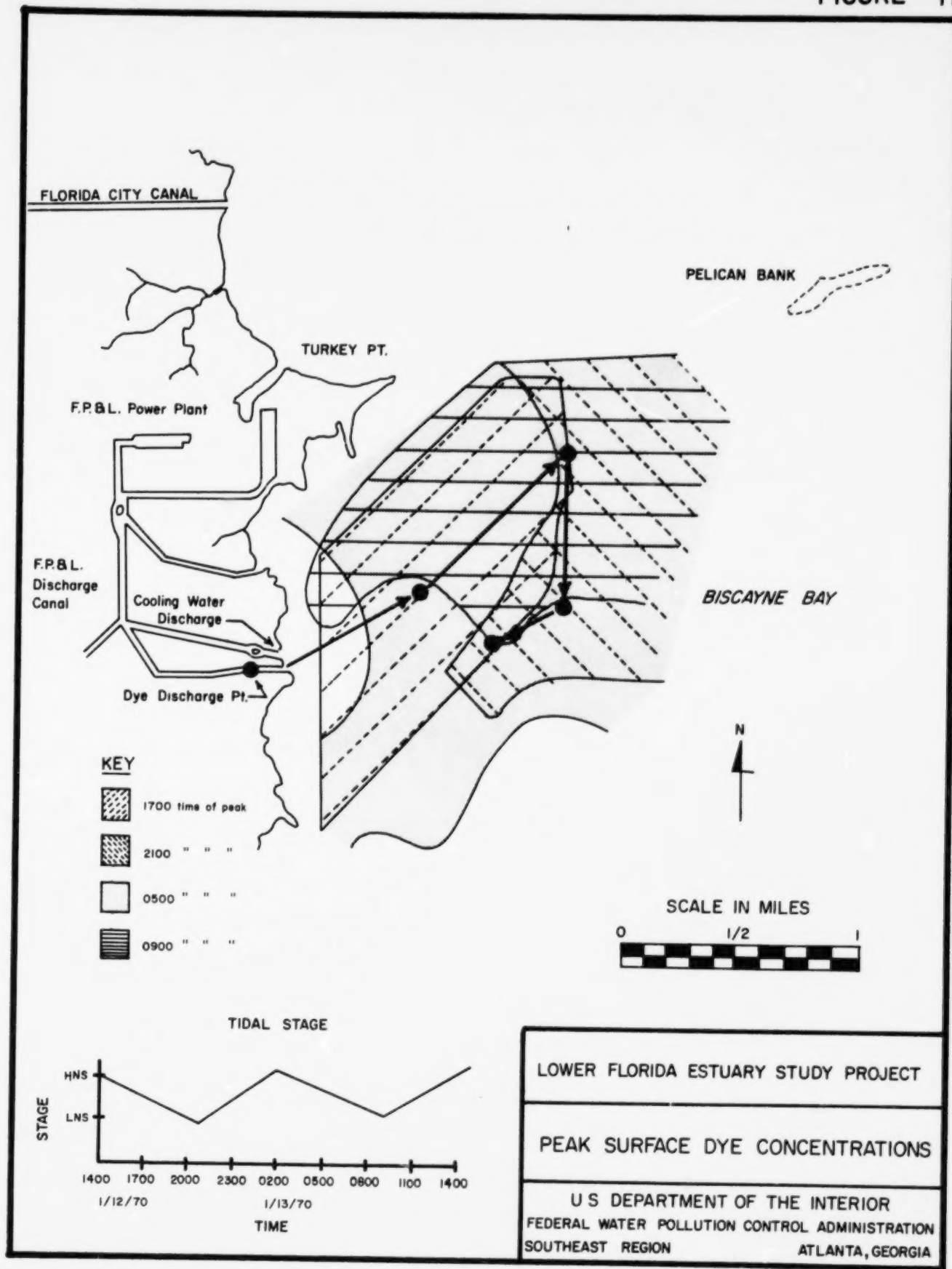
The dye moved very slowly initially, taking approximately 45 minutes to one hour to clear the mouth of the effluent canal (Figure 11). After exiting from the canal, the dye began to rapidly disperse and move northeastward on the ebbing tide. Peak concentrations were found just east of Turkey Point, between high-water and low-water slack conditions. Just after low-water slack conditions, the peak concentrations continued

24-a

TABLE 6
SUMMARY OF CHEMICAL DATA
CARD SOUND
1/15/70

STATION	ALKALINITY mg/l	TURBIDITY JCU	AMMONIA mg/l as N	NITRITE NITRATE mg/l as N	TOTAL KJELDAHL NITROGEN mg/l as N	TOTAL PHOSPHATE mg/l as P	BIOCHEMICAL OXYGEN DEMAND * mg/l
CS-1-T	164	1	0.03	0.015	0.88	< 0.05	0.2
CS-1-B	154	1	0.03	0.013	0.47	< 0.05	1.3
CS-2-T	153	1	0.08	0.020	0.38	< 0.05	2.4
CS-2-B	154	1	0.03	0.012	0.42	< 0.05	2.2
CS-3-T	152	1	0.05	0.017	0.35	< 0.05	0.8
CS-3-B	152	1	0.04	0.014	0.35	< 0.05	0.6
CS-4-T	154	2	0.04	0.018	0.46	< 0.05	-
CS-4-B	156	1	0.03	0.014	0.26	< 0.05	0.4
CS-5-T	169	4	0.10	0.035	0.53	< 0.05	2.9
CS-5-B	157	2	0.04	0.019	0.44	< 0.05	3.2

* 5 day 20°C



to move northeastward. Approximately $1\frac{1}{2}$ hours before HWS (@ 2:38 on 1/13/70), the dye-patch began moving south; two hours and 22 minutes after the HWS, the dye-patch was located approximately 1.1 miles northeast of the mouth of Grand Canal.

The dye, and hence heated water from the FP&L effluent canal, moves northeastward from the canal spreading over a large area of Biscayne Bay adjacent to Turkey Point and is persistent in concentration. The effluent from the canal is slowly dispersed, and is not readily flushed from the area. Thus, any cooling of water in the bay primarily occurs through exchange with the atmosphere rather than by mixing and dilution.

D. Temperature Effects

The Federal Water Pollution Control Administration conducted thermal studies of Lower Biscayne Bay from April to August 1968. This report is included as Appendix A. (6) Monitoring on a reduced scale was continued through the winter, spring and summer of 1968-69. In the late summer of 1969, full-scale thermal studies were again undertaken.

During the April-August 1968 study, a total of ten stations were established, several of which were beyond any possible influence of the heated water effluent. Maximum temperatures at stations close to the discharge canal were from 3° to 9° F higher than at control stations, and statistical analysis showed that these differences were significant and not merely the result of natural diurnal variation.

Furthermore, the daily fluctuations in temperature were much greater at the stations near Grand Canal than at the control stations. Two control stations (C-6 and E-9) had maximum daily temperature fluctuation of 3° to 4° F, while two stations near Grand Canal (H-13-A and H-14) had maximum daily fluctuations of 9° and 7° F, respectively.

The maximum hourly rate of temperature change was found at stations H-13-A and H-13 and amounted to 3° F per hour.

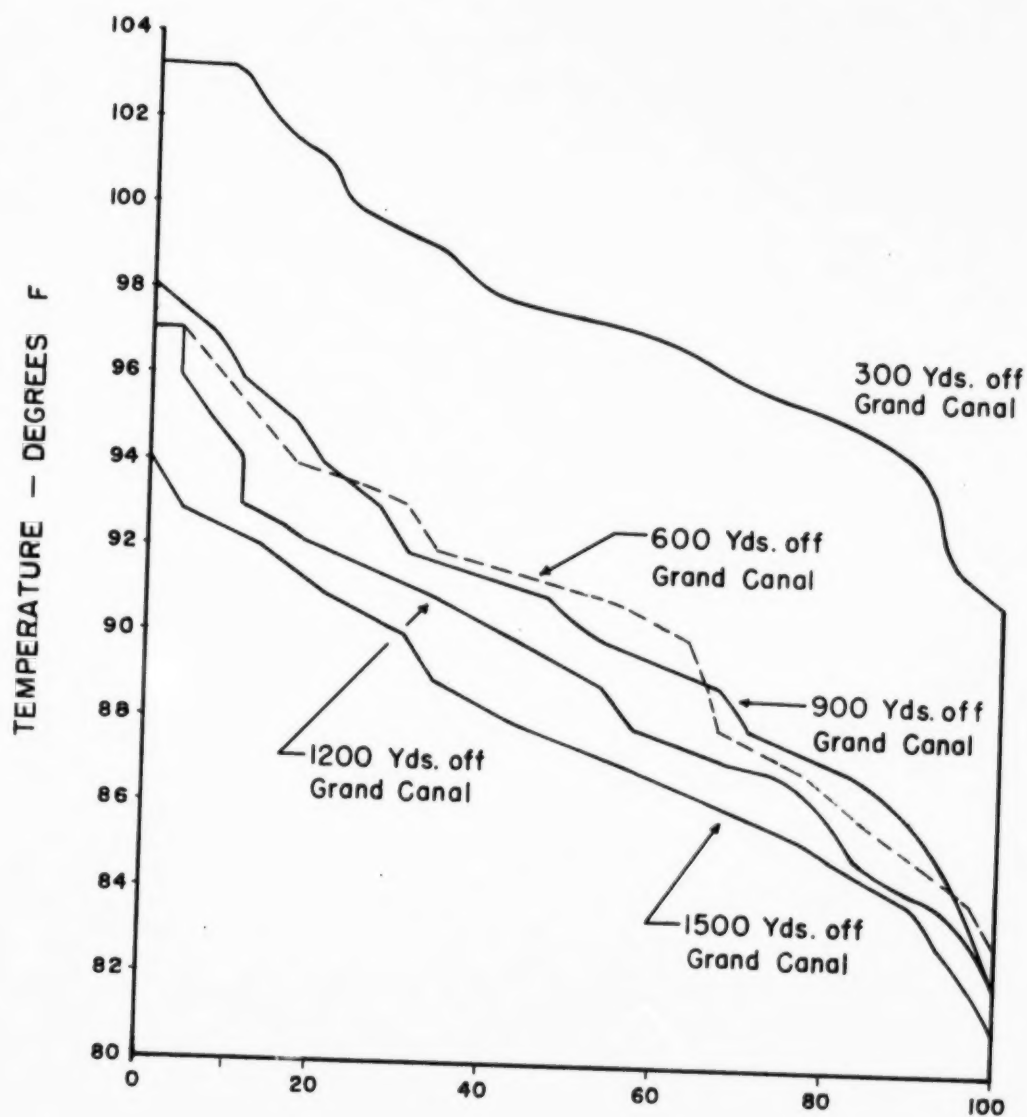
Numerous isotherm plots under various wind and tide conditions indicated that the movement of the heated water was in a generally northeasterly direction around Turkey Point.

A critical temperature condition occurred in June 1969. Figure 12 shows the percent of the time the temperature equalled or exceeded various levels at each of two stations along a 75° transect from Grand Canal. At 300 yards, the maximum daily temperature equalled or exceeded 90° F on all days. The maximum daily temperature observed was 103° F. At 1200 yards off Grand Canal, the maximum daily temperature exceeded 90° F on 43 percent of the days and reached a maximum of 97° F. These maximum temperatures resulted in a massive fish kill which will be described in subsequent sections.

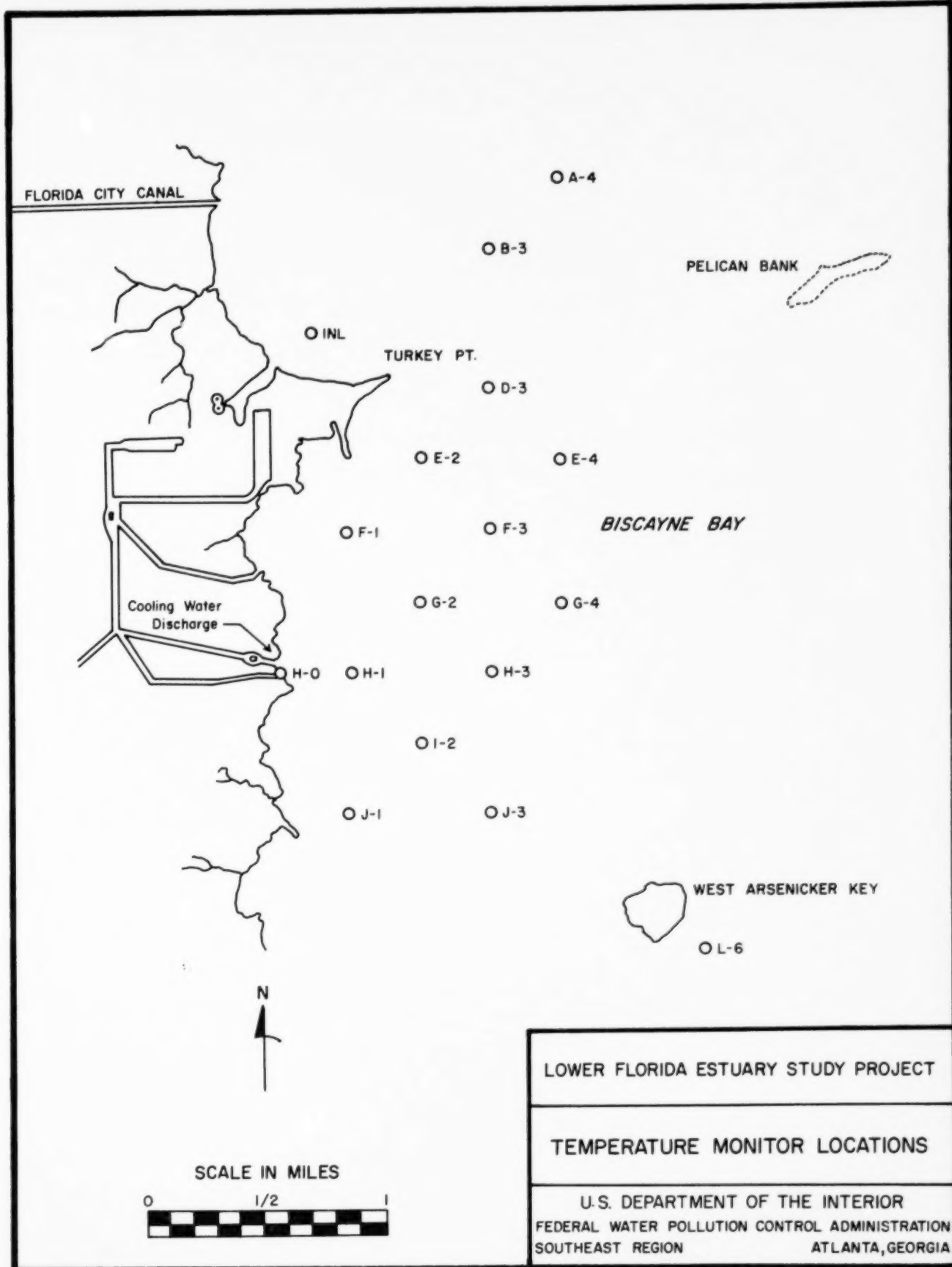
The first full month for which data are available from the present temperature monitoring program is August 1969. Figure 13 shows the location of the automatic monitors. Temperatures as high as 95° F occurred up to 1000 yards east and 1500 yards north of Grand Canal. The isotherms of the monthly mean of the daily maximum temperature

FIGURE 12

LOWER BISCAYNE BAY 75° MAGNETIC FROM
GRAND CANAL
JUNE 1969



PERCENT OF DAYS THE MAXIMUM DAILY
TEMPERATURE EQUALLED OR EXCEEDED
THE TEMPERATURE SHOWN.



indicates that the 90°F isotherm extends 1000 yards east, 1000 yards south and to the shores of Turkey Point on the north, or an area of at least 620 acres (Figure 14).

The isotherm field of temperatures which were equalled or exceeded 10 percent of the time during August 1969 indicates that a temperature of 90°F was exceeded throughout an area of over 620 acres (Figure 15).

The observed monthly maximum temperature isotherms for August 1969 (not necessarily simultaneous occurrence) indicate that, in the affected area, temperatures were in excess of 92°F and were as high as 99°F (Figure 16).

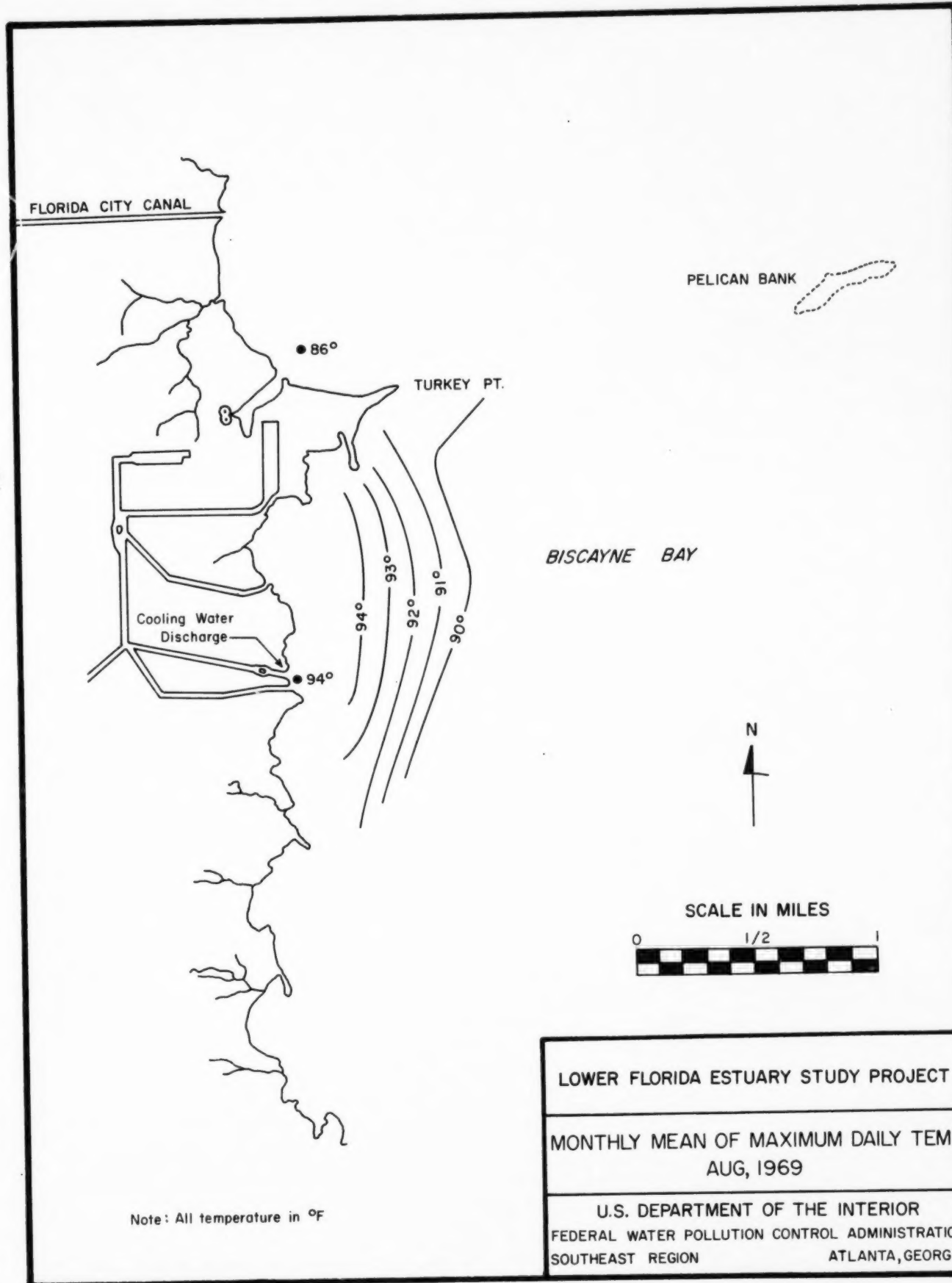
Temperatures were also measured at the cooling water intake location north of Turkey Point. The mean temperature during August 1969 was 85.5°F. The mean of the maximum daily temperature was 86.0°F. The maximum temperature observed during August 1969 was 88°F.

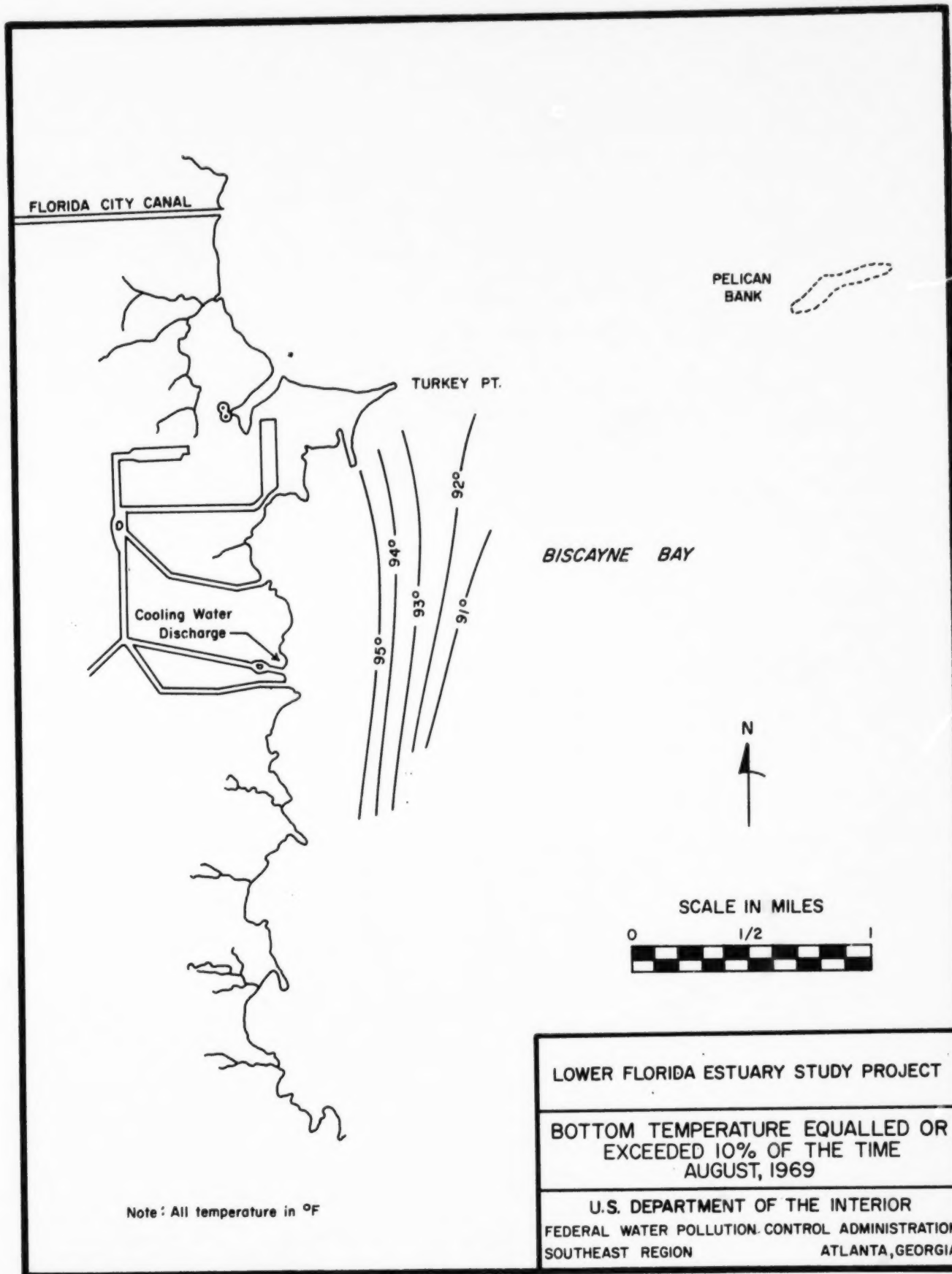
Cooling water effluent from the Florida Power and Light Turkey Point facility increased the monthly average of the maximum daily temperatures of at least 620 acres of Lower Biscayne Bay by more than 4°F. At the mouth of Grand Canal, the mean of the maximum daily temperature of 94°F during August 1969 was 8°F greater than intake temperature.

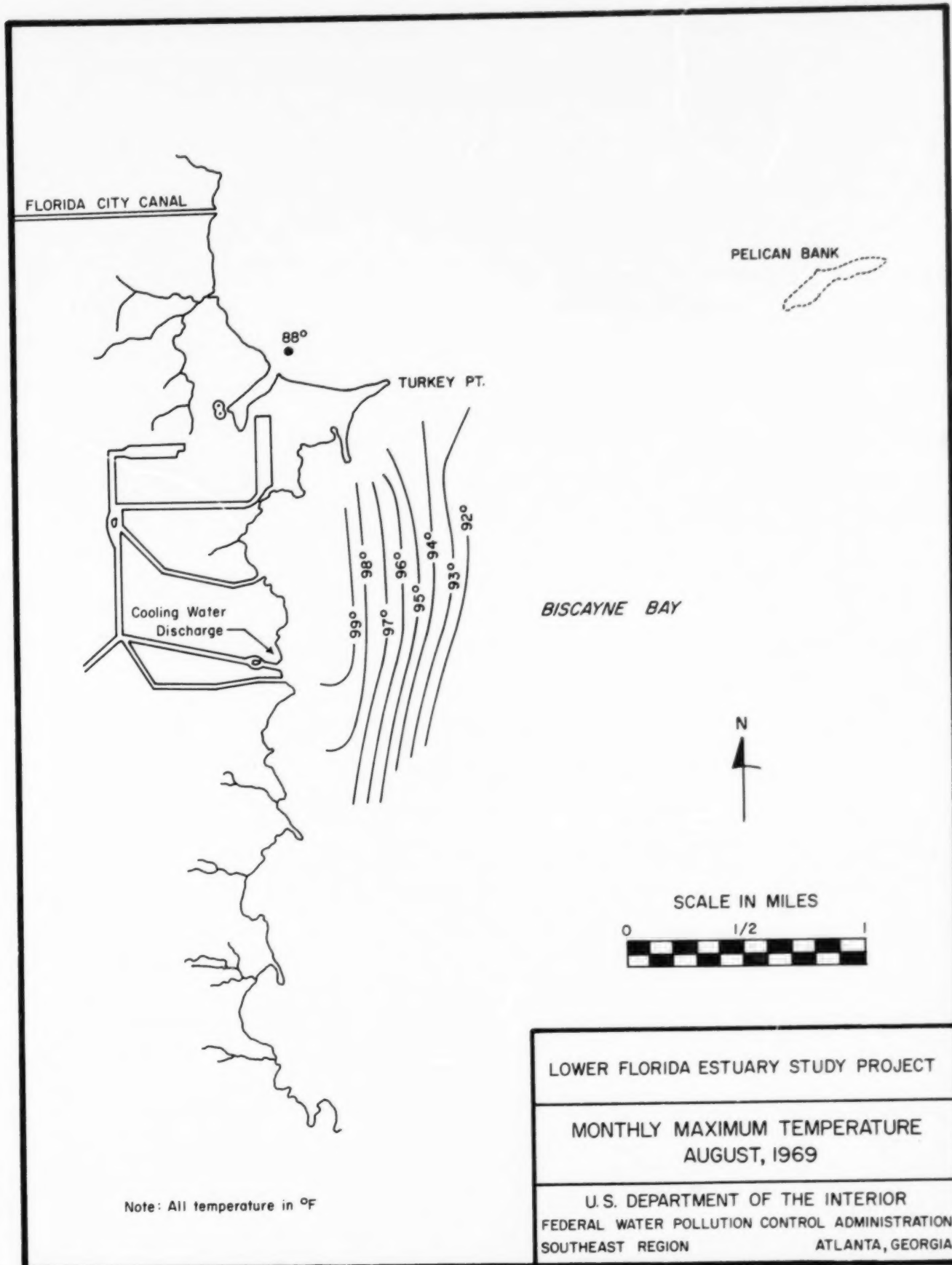
E. Biological Effects

1. Biscayne Bay

Biological studies conducted in Lower Biscayne Bay by the Federal Water Pollution Control Administration in the vicinity of







Florida Power and Light's Turkey Point power plant were initiated during late July 1968.

a. 1968

Near the mouth of Grand Canal, a barren, lifeless zone of denuded sediments extending several hundred yards into the bay was noted. Closer inspection revealed that the denuded sediments were covered with what appeared to be irregular mats of green or bluegreen microalgae. There were, however, none of the rooted plants or attached benthic algae that dominate the subtidal aquatic vegetation common to similar areas of the bay where sediments of sufficient depth exist. The area of barren sediment extended from 200 to 300 yards into the bay in the shape of a lopsided fan, covering an area estimated at 8 to 10 acres.

By late November 1968, an extension of the desolate area and marked erosion of exposed, unconsolidated bay sediments had occurred. Depressions within the affected area were filled with mangrove peat and decomposed Thalassia rhizomes, attesting to erosion deep into the soft sediments by swift currents at the mouth of Grand Canal. The area of denuded and seriously eroded sediments had increased in area to an estimated 40 to 50 acres. The soft, rich upper sediment layers were totally removed leaving the more consolidated mangrove peat, and in places, a layer of sand derived from dredging the canal.

Beyond the stark barren zone, in line with Grand Canal and well within the plume of heated water issuing from Grand Canal, a Thalassia bed was marked during mid-September which appeared unhealthy.

Upon closer inspection, the turtle grass blades were found to be coated with a heavy gelatinous material composed partly of epiphytic growths. Most of the grass blades had lost their bright green color, their vigor, and appeared brown and lifeless. Dead leaves cast from the plants littered the sediments. Benthic algae and invertebrates common to grass beds unaffected by heated effluents were conspicuously absent from the area characterized by sick and dying grass. Control study areas in nearby turtle grass beds were found to harbor swarms of small forage fish, molluscs, hermit crabs, estuarine corals, and crustacea living within the grass bed, in and upon the sediment, and upon the Thalassia blades as well. In addition, a variety of sessile green algae and mats of drifting red algae carpeted the bay bottom in unaffected areas.

By mid-November 1968, the sickened grasses observed earlier had completely succumbed and been carried away, leaving the exposed sediments which had begun to erode. An underwater search of an area 500 yards offshore from the mouth of Grand Canal showed that few living plants remained and that none of the usual invertebrate animals populating "grass bed" environments remained. A zone of nearly complete destruction of the plant and animal life extended from the mouth of Grand Canal into the bay for 500 to 700 yards, affecting an overall area of about 100 acres. Beyond the limits of the area grossly affected by the heated effluents, extending to between 700 and 1000 yards offshore from Grand Canal, there was a transition zone characterized by varying degrees of damage. It is estimated that the total affected

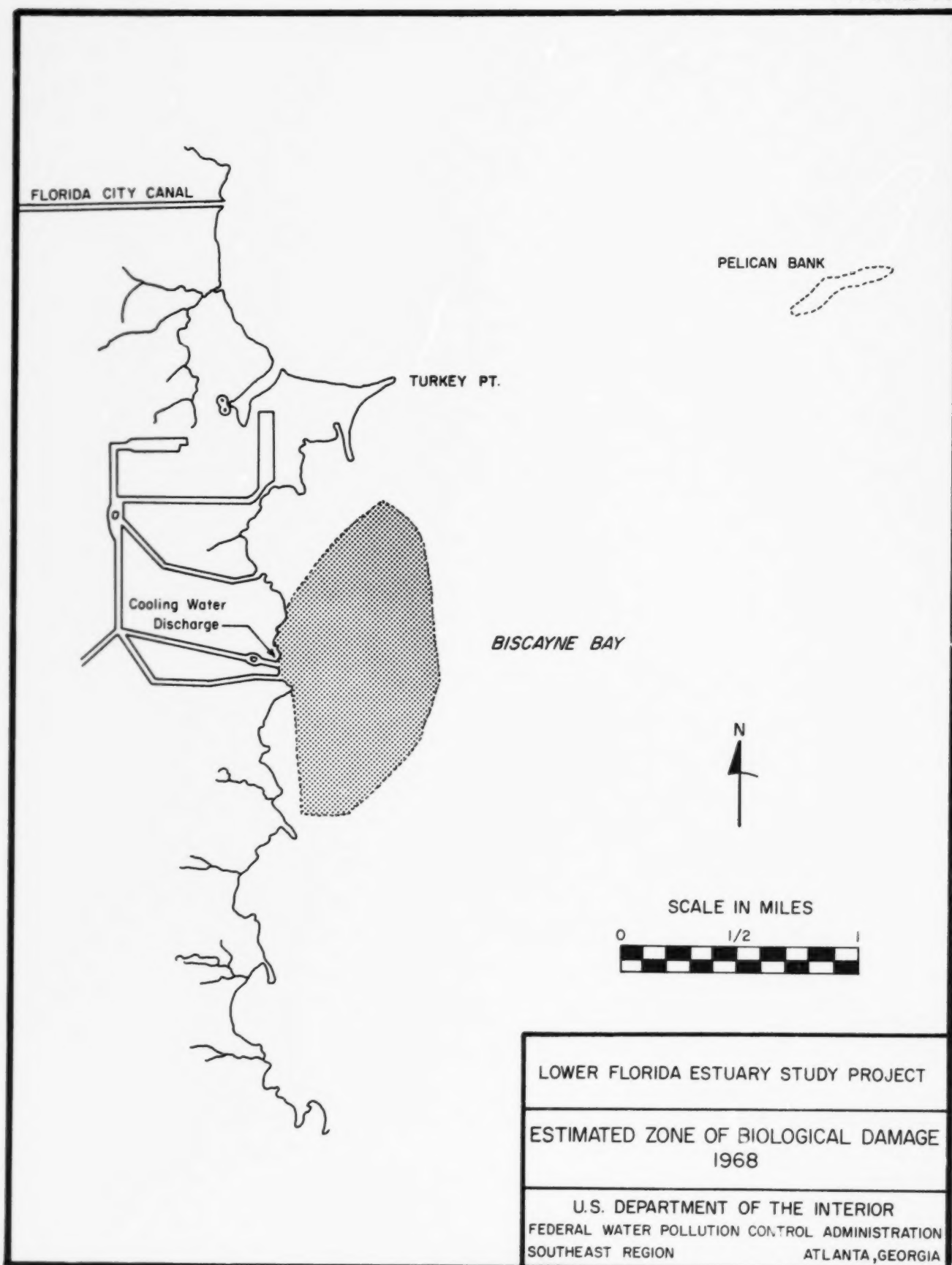
area, including the outer areas evidencing at least a moderate degree of damage, encompassed some 300 acres (Figure 17).

In early February 1969, the previously denuded and eroded sediments were covered by diatom growths, patches of Diplanthera, the hardy green algae Batophora, and a few red algae. There were few remains of the previous inhabitants of the area.

b. 1969

Biological studies in 1969 commenced on May 1. A transect was established extending from the mouth of Grand Canal, E-NE (approximately 75° magnetic) into Biscayne Bay, a distance of 1500 yards.

Observations recorded during May and June showed that while areas outside the immediate vicinity of heated effluent influence had experienced a spring re-growth, a small area of perhaps 10 acres near the mouth of Grand Canal remained devoid of the characteristic near shore benthic communities common to South Biscayne Bay. Aerial photographs taken during mid-June 1969 clearly show the stark, barren sediments, pockets of mangrove peat and Thalassia rhizomes, the calcareous sands washed from Grand Canal, and patches of Diplanthera at the fringes of the bald area. Traces extending from the canal bayward were cut by boat propellers followed by erosion of sediments along the disturbed track. These observations were verified by underwater examination of the area. Underwater exploration also revealed a rock rubble habitat at the mouth of the canal where stone crabs (Menippe mercenaria) and blue crabs (Callinectes sapidus) had taken up



residence. The exposed sediments near the mouth of the canal were colonized by green and bluegreen micro-algae and alternately by prolific growths of diatoms. The dominant form colonizing the sediments during May and June 1969 was identified as the green algae, Boodleopsis pusilla. The sediment situation was critical since micro-algae possess little ability to bind sediments, thereby protecting them from erosion by wave action and currents.

Mixed with the Diplanthera fringe at the outer edges of the barren zone were populations of Acetabularia crenulata and Batophora oerstedii, robust green algae that had re-established themselves during the cooler winter months. Beyond the fringe, at the 400-yard marker, a sparse growth of turtle grass (Thalassia testudinum) had developed from rhizomes that had been protected deep in the bay sediments. In addition to the Thalassia were a few sessile green algae of the genera Halimeda, Penicillus and Cladophoropsis; a few small coral colonies (Siderastrea sp.); chicken liver sponges, and a few other invertebrate animals. Thalassia re-growth at 400 yards was quite sparse; while at 500 yards, re-growth had become somewhat more dense. Progressively better colonization occurred with greater distance from the mouth of Grand Canal. Thus, the area between the 400-yard marker and the 1200-yard marker along the 75° transect was characterized by a gradient of increased density and diversity of both plant and animal life. Within this zone of re-growth, a host of tiny immature crabs (several genera and many species represented), shrimp, a wide variety of molluscs, pistol shrimp (species of the

genus Alpheus), corals (Siderastrea sp.), sessile green algae (species of the genera Halimeda, Penicillus, Caulerpa, Udotea, Cladophoropsis), hermit crabs, small bottom fish, sponges, and the ubiquitous red algal mat, had re-established sizeable populations.

Outside the 500-yard marker, the characteristics of the bay floor undergo a transition from the uniformly deep organic-rich near-shore sediments to an area where sediments blend alternately with an exposed limestone base covered lightly with shell fragments and calcareous sand. On the outer edges of this zone, and on further into the mid-portions of southwest Biscayne Bay, deep sediments are confined to roughly circular pockets, perhaps 100 feet in diameter. These pockets of sediment are invariably dominated by turtle grass (Thalassia testudinum), mixed with smaller densities of sessile green algae. The surrounding lightly-sedimented limestone base supports a wide variety of attached plants and animals, including numerous types of sponges, corals, a wide variety of algae, gorgonians, brittle stars, tiny starfish, burrowing crustacea and worms, limpets, a multitude of molluscs, including many types of clams, snails, mussels, worm shells and scallops, as well as burrow-dwelling fish, and hermit crabs.

On June 5, 1969, changes in benthic populations were being noted in the areas affected by heated effluents from Grand Canal. Even though small fish, shrimp, crabs, amphipods, brittle stars, etc., were noted as close as 200 yards to the outfall, the coral colonies (Siderastrea sp.) had all expired at 400 yards and 600 yards, and some

were dead at 800 yards. In addition, a temperature inversion was noted; that is, warmer water was lying on the bay bottom. By June 19, 1969, other species were disappearing, particularly at the inshore stations. The Thalassia bed at 600 yards had begun to lose its green color and was being coated by a brown gelatinous material. Some of the macro-algae had died at 800 yards; 50 to 70 percent of the corals were dead; the Thalassia was coated and epiphytiated. At 1000 yards, an increasingly large percentage of the Thalassia blades were losing color and vigor. No noticeable problems were observed beyond 1000 yards.

On June 25, unusually turbid waters and concomitant high temperatures were noted. On June 27, the bay bottom along the transect was searched and numerous dead pistol shrimp, blue crabs, spider crabs, dead algae, stone crabs, and molluscs were found. Dead animals were particularly numerous shoreward from the 1000-yard marker. On June 28, the bay bottom from 1500 yards along the transect to the mouth of Grand Canal was thoroughly searched. The bay bottom was littered with dead plants and animals, including sponges, spider crabs, blue crabs, corals, pistol shrimp, clams, snails, mussels, and several varieties of fish in addition to the wilted and browned green algae, species of the genera Anadyomene, Udotea, Penicillus, Halimeda, Caulerpa, Rhizocephalus, Cladophoropsis and Dictyosphaeria.

Within the mouth of Grand Canal, the dead remains of from 30 to 50 stone crabs and blue crabs were found. Outside the mouth of the canal and to the 500-yard marker, blue crabs, stone crabs, pistol

shrimp, and a variety of gastropod molluscs dominated the dead animals found. Beyond the 500-yard markers, were found dead sponges (including species of the genera Ircinia and Spheciospongia), a variety of dead sessile green algae, including species of the genera Caulerpa, Udotea, Penicillus, Halimeda, and Anadyomene; dead molluscs included the cross barred venus (Chione cancellata), prickly cockle (Trachycardium egmontianum), banded tulip (Fasciolaria hunteria), true tulip (Fasciolaria tulipa), calico bay scallops (Aquiptecten gibbus), worm shells (Vermicularia spirata), limpets (Acmaea sp.), and others; killed crustacea included the previously mentioned pistol shrimp, blue crabs, and stone crabs. Thousands of dead fish were reported south of Turkey Point on June 26, 1969.^{2/}

To determine the magnitude of the area of bay bottom affected and to assess the degree of damage caused by the overheating of the bay during late June, a grid pattern of study sites located at 500-yard intervals was plotted on a map to include the portions of Biscayne Bay in the vicinity of Turkey Point affected by heated discharges. A thorough underwater examination, corresponding to the sites in the bay plotted on the map during July 1969 revealed severe damage to benthic plant and animal populations, including corals, sponges, sessile green algae, crustacea, and molluscs in an area extending 1000 yards east, 1000 or more yards north and 500 or more yards south from the mouth of Grand Canal. An area evidencing a moderate degree of damage to benthic inhabitants extended east-

^{2/}

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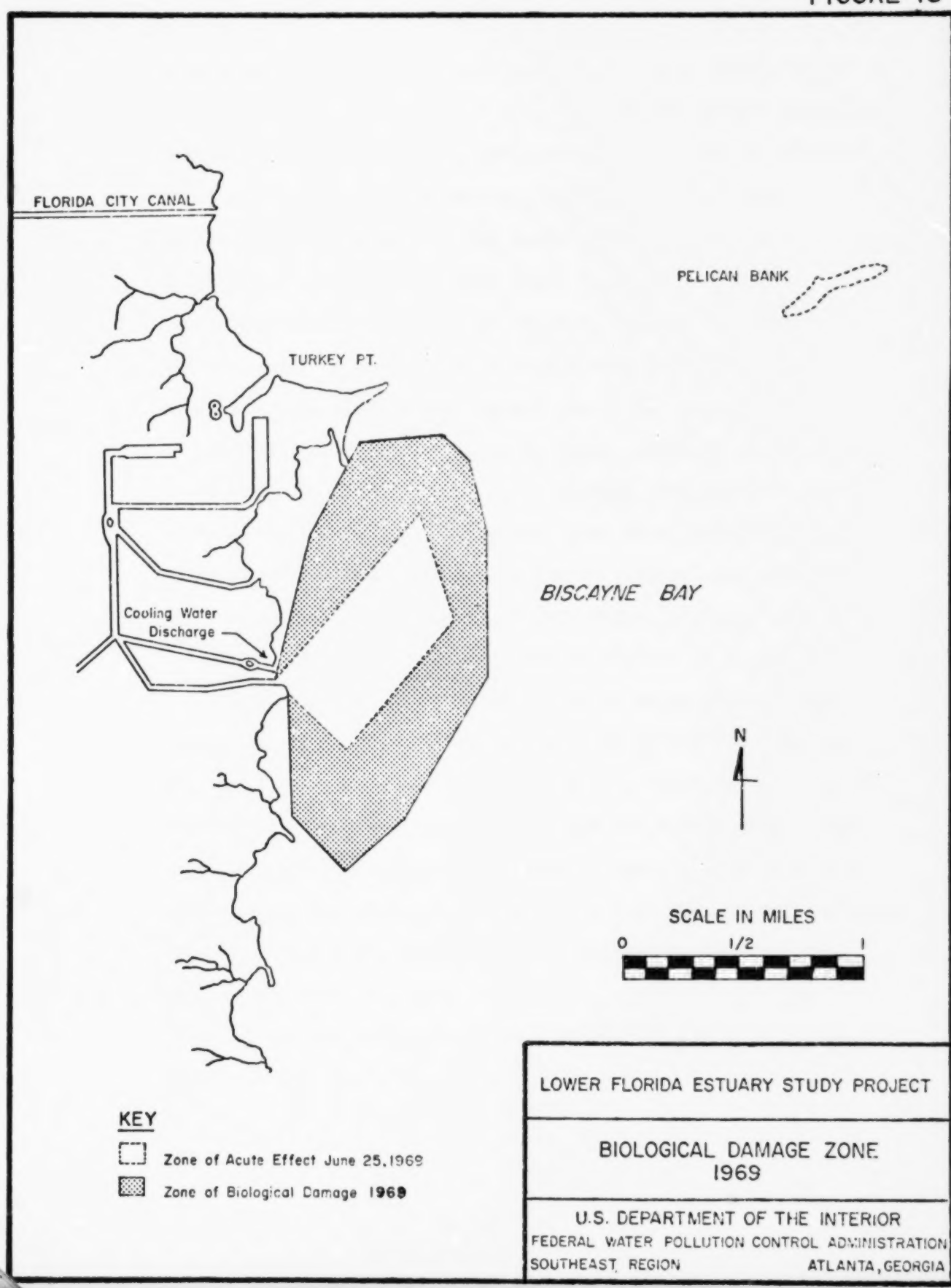
northeast from the mouth of Grand Canal to a point 1500 yards into Biscayne Bay. Dead and seriously damaged benthic plants and animals were observed along a line extending more than 1500 yards north and at least 500 yards south from a point located 1000 yards due east from the mouth of Grand Canal. The shape of the kill zone resembled the isotherm diagrams depicting the predominantly northeasterly flow of heated effluents past Turkey Point. The June 25 kill affected an area of Biscayne Bay totaling at least 570 acres. Observations conducted during mid- and late-July revealed that additional damage had occurred south from the mouth of Grand Canal which encompassed an additional 100 or more acres. Thus, the total estimated area of damage in Biscayne Bay, occurring during the summer months of 1969, based solely on the lethal effect of overheating, amounted to about 670 acres of bay bottom (Figure 18).

Excessive temperatures recorded on June 25--and for several days thereafter--killed all of the crabs that had taken residence within the rock pile at the mouth of Grand Canal. The hardier plants occupying the fringe zone outside the denuded sediments off the mouth of Grand Canal were again eliminated. The Thalassia that had re-grown at 500 yards was subject to a complete re-kill, with complete defoliation by September 1969. All other benthic life forms commonly inhabiting the grass bed environment were likewise absent.

Stations located 500 yards north and 500 yards south of a point 1000 yards due east of Turtle Point exhibited approximately 50 percent defoliation of Thalassia by September 1969. The commonly

35a

FIGURE 18



associated sessile green macro-algae were sparse or absent; the vast majority of coral colonies were dead, and the benthic invertebrate population (snails, clams, sponges, etc.) was drastically reduced.

The empty shells of killed molluscs littered the substrate; particularly noticeable were the shells of the small mussel Brachidontes exutus and the worm shell, Vermicularia spirata.

Both of these species had become unusually abundant at inshore stations prior to the occurrence of excessive summer water temperatures. A large population of common intertidal scavenger snails (i.e., Nassarius vibex and Prunum apicinum), which had presumably responded to an increased food supply brought about by the demise of other species at centrally located study sites, was likewise appreciably reduced by excessive bay water temperatures. There were few species, and a small number of individuals, making up this surviving population that remained viable at these study sites.

At sampling sites located 1500 yards north and 1500 yards south from the mouth of Grand Canal and 1000 yards from shore, the skeletal remains of killed invertebrates were evidence of earlier damage. In some instances, however, there was partial re-growth of new living sponge tissue upon the skeletal remains. Some genera of sessile green macroalgae (i.e., Penicillus and Halimeda) had initiated new growth during late August and early September, whereas others were sparse, rare, or totally absent.

There was progressively less evidence of damage at stations 1500 yards east from the mouth of Grand Canal and at stations north

and south from that point. Only the green macroalgae, Caulerpa paspaloides, Caulerpa sertularioides, Udotea flabellum and Udotea conguiltinata; the most sensitive sponges; the corals Siderastrea sp. and Solenastrea hyades; and certain common molluscs, i.e., Vermicularia spirata and Brachidontes exutus, were among those constituting the most dependable indicators of thermal stress and damage. Stations outside the area of thermal stress were inhabited by spiny lobsters (Panulirus argus), a large variety of swimming crabs, species of the genera Callinectes and Portunus, stone crabs, spider crabs, pistol shrimp (Alpheus), brittle stars (class, Ophiuroidea), tiny starfish (Echinaster sentus), a host of molluscs, sea anemonae, gorgonids, and all the other life forms comprising the normal flora and fauna of an undisturbed habitat common to Lower Biscayne Bay.

Degradation and destruction of bottom fauna and fish were observed in Lower Biscayne Bay in an area of 300 acres during 1968 and 670 acres during 1969. The area of biological degradation coincides with the observed area of increased water temperatures. During August 1969, water temperatures in the area of biological degradation were from 4°F to 8°F greater than the monthly mean of the maximum daily temperatures at the cooling water intake. Water quality indicators, other than temperature, demonstrate excellent conditions. The cause of the biological degradation and destruction during 1968 and 1969 in Lower Biscayne Bay is the discharge of waste heat from the Florida

Power and Light Company Turkey Point generating plant. The water quality standards of the State of Florida require no damage to aquatic life or vegetation as the result of increased temperature. This criterion is being violated by the discharge of cooling water from the Turkey Point generating plant.

2. Card Sound

A preliminary biological reconnaissance of Card Sound was conducted during late September 1969. Eight sites were selected at intervals across the south end, middle, and north end of the Sound. Two other sites near the mouth of Model Land Canal had been visited previously during the course of servicing thermographs.

The substrate of Card Sound is variable, with sand and shell dominating some areas and accumulations of soft sediments dominating other areas, with a blending of these into mixed sediment types between. As in Biscayne Bay, pockets of sediment are found isolated by a more solid substrate. These sediment pockets support a lush and varied flora, dominated by Thalassia.

A wide variety of benthic plants and animals was noted, including algae, species of the genera Caulerpa, Udotea, Halimeda, Penicillus, Rhipocephalus, Batophora, Acetabularia, Anadyomene, a host of red algae varieties that carpeted the substrate in many areas. There were corals, species of the genera Porites, Solenastrea and Siderastrea, gorgonians, sea anemonae, colonial tunicates, an abundance and wide variety of sponges, sea urchins, species of the genera Diadema

and Lytechinus, a number of molluscs, including bay-scallops and pen shells. Most conspicuous, however, were the empty mollusc shells littered about the dens of the stone crabs. Stone crabs (Menippe mercenaria) and the spiny lobster (Panulirus argus), both valuable commercial species, were abundant where suitable cover prevailed. Also found were sea horses, spider crabs, terebellid worms, and mounds presumably thrown-up by burrowing shrimp.

There was a variety and abundance of the green alga Caulerpa. Caulerpa prolifera, C. mexicana, C. paspaloides, C. sertularioides, C. cupressoides, C. racemosa and C. ashmeadii were all found in abundance in the southeast corner of Card Sound. There was C. paspaloides and C. sertularioides throughout Card Sound in abundance.

From the biological population composition, it appears that Card Sound is more marine in character than Biscayne Bay and that it is a more stable habitat physically and chemically--less prone to extremes. There appears to be greater Thalassia cover in Card Sound as a whole than in south central Biscayne Bay. Although sediment depths are not great, there is sediment of sufficient depth in much of the Card Sound basin to permit luxurious Thalassia bed development. A report prepared for Florida Power and Light determined sediment depths at 32 stations in Card Sound. (7) Seventeen of these stations, or nearly 50 percent, had sediment depths of greater than 25 cm which is suitable for Thalassia growth.

There is a warm turbid layer of water along the bottom of Card Sound--a thermal inversion--that exhibited temperatures several

degrees above overlying water masses. The thermal inversion layer varied from 6 to 10 inches to 4 to 6 feet deep. Thermographs off the mouth of Model Land Canal recorded temperature maxima of from 91° to 92°F occurring for several days at a time.

Florida Power and Light Company has proposed a discharge of heated effluent to Card Sound after 100% dilution with Biscayne Bay water. A report prepared by the University of Florida, College of Engineering reveals that the introduction of 8500 cfs (5.5 billion gallons per day) of cooling water will significantly elevate water temperature in Card Sound. (8) The cooling water would be discharged to Card Sound with a temperature increase of at least 6°F above intake levels in Biscayne Bay. An area of 1000 acres would exhibit average summer temperatures of about 94°F and the same area would have temperatures in excess of 98°F , five percent of the time. This represents about 7% of the total area of Card Sound. If cooling water from the Turkey Point power facility is discharged to Card Sound, as presently proposed by the Florida Power and Light Company, temperatures in excess of 95°F can be expected in at least 35% of Card Sound five percent of the time. The biological effects which may be induced in both Biscayne Bay and Card Sound by the salinity and circulation changes which implementation of this proposal would cause have not been evaluated.

VIII. DISCUSSION

The Turkey Point Power Plant of the Florida Power and Light Company under present operating conditions discharges 1270 cfs or 820 million gallons per day of cooling water at elevated temperatures to Lower Biscayne Bay. Under normal operating conditions, the temperature increase of the cooling water was never less than 3.3°F during the summer of 1969. An increase of 12°F or greater was observed 16% of the time. Under the most conservative present operating conditions, the increase will exceed 10°F at least 16% of the time (July 1969). This cooling water effluent, discharged through Grand Canal, increased temperatures of the receiving water above 90°F at least 10% of the time, over an area of 620 acres during August 1969. With the construction and operation of the nuclear powered units, the volume of necessary cooling water will be increased nearly four times to 2.75 billion gallons per day and the waste heat will be four times greater than that presently discharged. If this waste heat is discharged to Lower Biscayne Bay, the area of increased temperatures in the bay will be substantially enlarged.

Extensive biological damage to bottom fauna and fish has been observed in the area of increased temperature. The cause of this biological damage to the bay is the waste heat discharge of 1270 cfs from the Florida Power and Light Turkey Point facility. There is no source of artificial organic or chemical pollution which is affecting the water quality of Lower Biscayne Bay. Water quality indicators, other than temperature, demonstrate excellent conditions. Based upon lethal effects only, the biological degradation zone encompassed

about 670 acres during the summer of 1969 under the present operating conditions at Turkey Point. This includes no evaluation of the more subtle, long term effects of heat stress upon the biota. When all generating units are in operation, the acute biological damage will occur over a significantly enlarged area for a longer period of time. To prevent further biological damage due to the discharge of cooling water effluent from Florida Power and Light Company's Turkey Point facility, a waste heat control program is urgently required and should be immediately implemented.

The National Technical Advisory Committee in its report to the Secretary of the Interior, April 1, 1968, set strict guidelines for the establishment of temperature criteria. In part, this report states: "All important species, including the most sensitive, must be protected. In the tropics or subtropics, optimum temperatures for many forms are only a few degrees lower than maximum lethal temperatures. Great care should be exercised therefore to prevent harmful increases in maximum summer temperatures in tropical areas." (9)

As a guideline for establishing incremental limits, NTAC recommends the following: "Monthly means of the maximum daily temperatures, recorded at the site in question and before the addition of any heat or artificial origin, should not be raised more than 4°F during the fall, winter and spring (September through May) or by more than 1.5°F during the summer (June through August). The rate of temperature change should not exceed 1°F per hour except when due to natural phenomena. Suggested temperatures are to prevail outside of established mixing zones."

At locations remote from Turkey Point (not closer than 5000 yards from mouth of Grand Canal), the monthly average of daily maximum temperatures in 1968 were: June, 83.1°F ; July, 85.6°F ; August, 87.2°F . At selected stations in shallow water areas similar to that adjacent to Grand Canal, the monthly average of maximum daily temperature in August was 88.2°F (Table 7). Following the NTAC recommendations of 1.5°F incremental rise, this would produce a maximum allowable temperature of 89.7°F at the mouth of Grand Canal, a temperature which is now exceeded almost continuously from June through August under present operating conditions.

In a report of the Committee on Inshore and Estuarine Pollution (10) (referred to as the Hoover Committee Report), a group of 10 outstanding scientists in the field of marine ecology recommended, in reference to the Turkey Point plant: "The maximum permissible temperature at the outfall must not exceed 90°F ."

It is recommended that the waste heat generated by the Florida Power and Light Company Turkey Point facility be abated such that the temperature of the receiving waters is not increased more than 1.5°F from June through August nor more than 4.0°F from September through May above the monthly mean of the maximum daily temperature. The Federal Water Pollution Control Administration, in cooperation with the Florida Department of Air and Water Pollution Control and the Florida Power and Light Company, should establish a temperature monitoring program to determine compliance with the above recommendation.

TABLE 7
MONTHLY AVERAGE OF MAXIMUM DAILY TEMPERATURE*
OF

June 1968	Station B-4	84.3
	C-6	82.5
	D-8	82.6
July 1968	Station B-4	85.6
August 1968	Station B-4	88.2
	C-6	86.2
	G-12	88.1

Stations B-4 and G-12 are in shallow water areas similar to that immediately adjacent to Turkey Point and Grand Canal.

*Temperature Studies, Lower Biscayne Bay, Florida, U. S. Department of the Interior, Federal Water Pollution Control Administration, Southeast Water Laboratory, October 1968.

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